

UC-NRLF



B 4 182 793

BERKELEY  
LIBRARY  
UNIVERSITY OF  
CALIFORNIA

EARTH  
SCIENCES  
LIBRARY

LIBRARY  
OF THE  
UNIVERSITY OF CALIFORNIA.

GIFT OF

*Gr. Brit. Geol. Survey.*

Class

438  
R716















MAR 2 1905

A  
HANDBOOK  
TO  
A COLLECTION OF THE  
MINERALS OF THE BRITISH ISLANDS,  
MOSTLY SELECTED FROM THE  
LUDLAM COLLECTION,

IN THE  
MUSEUM OF PRACTICAL GEOLOGY,  
JERMYN STREET, LONDON, S.W.

BY  
F. W. RUDLER, I.S.O., F.G.S.,  
LATE CURATOR OF THE MUSEUM.



LONDON:  
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,  
BY WYMAN & SONS, LIMITED, FETTER LANE, E.C.

And to be purchased from  
E. STANFORD, 12, 13, and 14, LONG ACRE, LONDON ;  
JOHN MENZIES & Co., ROSE STREET, EDINBURGH ;  
HODGES, FIGGIS & Co., GRAFTON STREET, DUBLIN ;  
From any Agent for the sale of Ordnance Survey Maps ; or through any  
Bookseller from the Ordnance Survey Office, Southampton.

1905.

*Price One Shilling.*

## GENERAL MEMOIRS.

SUMMARY OF PROGRESS of the GEOLOGICAL SURVEY for 1897, 1898, 1899, 1900, 1901, and 1902. Each 1s.  
 PLOCENE DEPOSITS of BRITAIN. By C. REID. 5s. 6d.  
 CRETACEOUS ROCKS of BRITAIN.—Vol. I. GAULT AND UPPER GREENSAND OF ENGLAND. 9s. Vol.  
 LOWER AND MIDDLE CHALK. 10s. Vol. III. UPPER CHALK. 10s. By A. J. JUKES-BROWNE and W. HILL.  
 JURASSIC ROCKS of BRITAIN.—Vol. I. YORKSHIRE, 8s. 6d. Vol. II. YORKSHIRE, Fossils, 12s.  
 C. FOX-STRANGWAYS. Vol. III. LIAS OF ENGLAND (Yorkshire excepted). 7s. 6d. By H. B. WOODWARD.  
 Vol. IV. The Lower Oolitic Rocks of England. 10s. By H. B. WOODWARD. Vol. V. The Middle and Upper  
 Oolitic Rocks of England. 7s. 6d. By H. B. WOODWARD.  
 BRITISH ORGANIC REMAINS. DECADES I. to XIII., with 10 Plates each. Price 4s. 6d. each 4to; 2s. 6d. each  
 MONOGRAPH I. On the Genus PTERYGOTUS. By T. H. HUXLEY and J. W. SALTER. 7s.  
 MONOGRAPH II. On the Structure of the BELEMNITIDÆ. By T. H. HUXLEY. 2s. 6d.  
 MONOGRAPH III. CROCODYLIAN REMAINS found in the ELGIN SANDSTONES. By T. H. HUXLEY. 1s.  
 MONOGRAPH IV. On the CHIMÆROID FISHES of the British Cretaceous Rocks. By E. T. NEWTON. 5s.  
 VERTEBRATA of the PLOCENE DEPOSITS of BRITAIN. By E. T. NEWTON. 4s.

*Museum Catalogues, &c.:*—

HANDBOOK to the MUSEUM of PRACTICAL GEOLOGY. 6d.  
 FOSSILS:—CAMBRIAN and SILURIAN, 2s. 6d.; CRETACEOUS, 2s. 9d.; TERTIARY and POST-TERTIARY, 1s.

## DISTRICT MEMOIRS.

MEMOIRS of the GEOLOGICAL SURVEY of GREAT BRITAIN. Vol. I. ESSAYS by DE LA BECHE and OTHERS.  
 21s. Vol. II. Part 1, MALVERN HILLS. By J. PHILLIPS. 21s. Part 2, ESSAYS. 21s. Vol. III. N. WALES.  
 By SIR A. C. RAMSAY. App., by J. W. SALTER and R. ETHERIDGE. 2nd Ed. 21s.  
 CAMBRIDGE. By W. H. PENNING and A. J. JUKES-BROWNE. 4s. 6d.  
 CORNWALL, DEVON, and WEST SOMERSET. INDEX to DE LA BECHE'S Report on. By C. REID. 1s.  
 DERBYSHIRE, NORTH. By A. H. GREEN, J. C. LE NEVE FOSTER and J. R. DAKYNS. 2nd Ed. By A. H. GREEN  
 and A. STRAHAN. 5s. 6d.  
 FENLAND. By S. B. J. SKERTCHLY. 3s. 6d.  
 HOLDERNESS. By C. REID. 4s.  
 ISLE OF MAN. By G. W. LAMPLUGH. 12s.  
 ECONOMIC GEOLOGY of ISLE OF MAN. 1s. 6d.  
 TERTIARY FLUVIO-MARINE FORMATION of the ISLE OF WIGHT. By EDWARD FORBES. 5s.  
 ISLE OF WIGHT. By H. W. BRISTOW. New Ed. By C. REID and A. STRAHAN. 8s. 6d.  
 ISLE of PURBECK and WEYMOUTH. By A. STRAHAN. 10s. 6d.  
 LAKE DISTRICT, NORTHERN PART OF. By J. C. WARD. 9s.  
 LANCASHIRE, SUPERFICIAL DEPOSITS of SOUTH WEST. By C. E. DE RANCE. 10s. 6d.  
 LONDON and PART of the THAMES VALLEY. By W. WHITAKER. Vol. I., 6s. Vol. II., 5s.  
 MIDLAND COUNTIES, TRIASSIC and PERMIAN ROCKS of the. By E. HULL. 5s.  
 NORFOLK and SUFFOLK, VERTEBRATA of the FOREST RED SERIES of. By E. T. NEWTON. 7s. 6d.  
 NORWICH. By H. B. WOODWARD. 7s.  
 RUTLAND, &c. By J. W. JUDD. 12s. 6d.  
 WEALD, (PARTS of KENT, SURREY, SUSSEX, and HANTS). By W. TOPLEY. 17s. 6d.

*Eruptive Rocks:*—

ERUPTIVE ROCKS of BRENT TOR. By F. RUTLEY. 15s. 6d.  
 FELSITIC LAVAS of ENGLAND and WALES. By F. RUTLEY. 9d.

*Iron Ores of Great Britain:*—

Part II. South Staffordshire. Price 1s. Part III. South Wales. Price 1s. 3d. Part IV. The Shropshire Coal  
 field and North Staffordshire. 1s. 3d.

*Coal Fields:*—

BURNLEY COALFIELD. By E. HULL, R. H. TIDDEMAN [and Others]. 12s.  
 YORKSHIRE COALFIELD. By A. H. GREEN, R. RUSSELL [and Others]. 42s.  
 EAST SOMERSET and BRISTOL COALFIELDS. By H. B. WOODWARD. 18s.  
 WARWICKSHIRE COALFIELD. By H. H. HOWELL. 1s. 6d.  
 CHEADLE COALFIELD. By G. BARROW. 2s.  
 LEICESTERSHIRE COALFIELD. By EDWARD HULL. 3s.  
 SOUTH WALES. (See under Sheet Memoirs, New Series).

*Sanitation and Water Supply:*—

SOILS and SUBSOILS from a SANITARY POINT of VIEW. By H. B. WOODWARD. 2s. 6d.  
 WATER SUPPLY of SUSSEX. By W. WHITAKER and C. REID. 3s.  
 WATER SUPPLY of BERKSHIRE. By J. H. BLAKE and W. WHITAKER. 3s.

*Gun Flints:*—

MANUFACTURE of GUN FLINTS. By S. B. J. SKERTCHLY. 16s.

## SHEET MEMOIRS of OLD SERIES MAPS.

London Sheet. Guide to the GEOLOGY of LONDON and NEIGHBOURHOOD. By W. WHITAKER. 6th Ed. 1s.  
 4. - - - FOLKESTONE and RYE. By F. DREW. 1s.  
 34. - - - PARTS of WILTS. and GLOUCESTERSHIRE. By A. C. RAMSAY, W. T. AVELINE, and E. HULL. 8d.  
 44. - - - CHELTENHAM. By E. HULL. 2s. 6d.  
 45. - - - BANBURY, WOODSTOCK, and BUCKINGHAM. By A. H. GREEN. 2s.  
 45 SW. - - WOODSTOCK. By E. HULL. 1s.  
 47. - - - N.W. ESSEX & N.E. HERTS. By W. WHITAKER, W. H. PENNING, W. H. DALTON, & F. J. BENNETT. 1s.  
 48 SW. - - COLCHESTER. By W. H. DALTON. 1s. 6d.  
 48 SE. - - EASTERN END of ESSEX (WALTON NAZE and HARWICH). By W. WHITAKER. 9d.  
 48 NW, NE. - IPSWICH, HADLEIGH, and FELIXSTOWE. By W. WHITAKER, W. H. DALTON, & F. J. BENNETT. 2s.  
 49 S, 50 SE. - ALDBOROUGH, &c. By W. H. DALTON. Edited, with additions, by W. WHITAKER. 1s.  
 49 N. - - SOUTHWOLD. By W. WHITAKER. 2s. 6d.



A  
HANDBOOK  
TO  
A COLLECTION OF THE  
MINERALS OF THE BRITISH ISLANDS,  
MOSTLY SELECTED FROM THE  
LUDLAM COLLECTION,  
IN THE  
"London"  
MUSEUM OF PRACTICAL GEOLOGY,

JERMYN STREET, LONDON, S.W.

BY  
F. W. RUDLER, I.S.O., F.G.S.,  
LATE CURATOR OF THE MUSEUM.



LONDON:  
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,  
BY WYMAN & SONS, LIMITED, FETTER LANE, E.C.

And to be purchased from  
E. STANFORD, 12, 13, and 14, LONG ACRE, LONDON ;  
JOHN MENZIES & Co., ROSE STREET, EDINBURGH ;  
HODGES, FIGGIS & Co., GRAFTON STREET, DUBLIN ;  
From any Agent for the sale of Ordnance Survey Maps ; or through any  
Bookseller from the Ordnance Survey Office, Southampton.

1905.

*Price One Shilling.*

66L6

EARTH  
SCIENCES  
LIBRARY

Gift  
Geol. Survey  
Gr. Brit

## PREFACE.

---

The Museum of Practical Geology has long possessed collections of British rocks and British fossils arranged with special reference to their mode of occurrence in the field, but until recently it has not possessed a general collection of British Minerals arranged on the same basis, although the materials for making such a collection were present in the Museum, mainly in the valuable series of specimens bequeathed by Mr. Henry Ludlam.

On the retirement of Mr. Rudler from the post of Curator, I was fortunately able to retain his services for the special purpose of arranging a collection on the lines above referred to. He has now completed the work, and upwards of 1,700 specimens have been duly arranged, labelled, and placed on view in the Museum.

Although the present Handbook has been prepared primarily as a guide to the collection, I am confident that it will be found to possess a permanent value quite apart from the specimens to which it relates. Whilst it is sufficiently explanatory to form a treatise which will prove of interest even to those who are unversed in mineralogy, it is detailed enough to be serviceable to scientific students, especially to students of geology and mining. The copious footnotes, with references to the original authorities consulted in the preparation of the work, are of great value and afford evidence of the thoroughness with which the subject has been dealt with.

I cannot allow the present opportunity to pass without placing on record my high appreciation of the services rendered to this Institution by Mr. Rudler during his long tenure of office as Curator, and of the great skill and knowledge which he has displayed in arranging the collection of British Minerals and in writing this Handbook.

J. J. H. TEALL,  
*Director.*

Museum of Practical Geology,  
Jermyn Street, London.

*December 21st, 1904.*

131313





## CONTENTS.

	PAGE
INTRODUCTION . . . . .	1
CASE I.—DIVISION 1.	
MINERALS OF CORNWALL AND DEVON.	
<i>Cassiterite and its associates</i> . . . . .	5
Cassiterite . . . . .	15
Stannite . . . . .	20
CASE I.—DIVISION 2.	
MINERALS OF CORNWALL AND DEVON— <i>Continued.</i>	
<i>Minerals associated with Cassiterite</i> . . . . .	21
Quartz . . . . .	21
Apatite . . . . .	23
Topaz . . . . .	25
Fluorite . . . . .	26
Fluellite . . . . .	26
Lithia-Mica . . . . .	27
Gilbertite . . . . .	27
Tourmaline . . . . .	28
Axinite . . . . .	30
Wolframite . . . . .	30
Scheelite . . . . .	31
Mispickel . . . . .	31
CASE II.—DIVISION 1.	
MINERALS OF CORNWALL AND DEVON— <i>Continued.</i>	
<i>Copper Sulphides and Sulpho-ferrites</i> . . . . .	33
Chalcopyrite . . . . .	35
Chalcocite . . . . .	37
Covellite . . . . .	38
Erubescite . . . . .	39
CASE II.—DIVISION 2.	
MINERALS OF CORNWALL AND DEVON— <i>Continued.</i>	
<i>Copper-bearing Minerals of the Gozzans</i> . . . . .	40
Cuprite . . . . .	42
Melaconite . . . . .	43
Native Copper . . . . .	44
Malachite and Chessylite . . . . .	45
Chrysocolla . . . . .	46
Chalcanthite . . . . .	46
Langite, Woodwardite, etc. . . . .	47
Connellite . . . . .	48
Atacamite, etc. . . . .	49

## CASE III.—DIVISION 1.

MINERALS OF CORNWALL AND DEVON— <i>Continued.</i>		PAGE
<i>Arsenates and Phosphates from the Copper-Gozzans</i>		50
Olivenite, Libethenite, etc.		51
Clinoclase and Cornwallite		52
Liroconite		52
Chalcophyllite		53
Bayldonite, etc.		53
Andrewsite, Chalcosiderite, etc.		53

## CASE III.—DIVISION 2.

MINERALS OF CORNWALL AND DEVON— <i>Continued.</i>		
<i>Ores of Lead, Zinc, Antimony, etc.</i>		54
Galena, Cerussite, and Pyromorphite		55
Silver Ores		56
Zinc Ores		58
Antimony Ores		59

## CASE IV.—DIVISION 1.

MINERALS OF CORNWALL AND DEVON— <i>Continued.</i>		
<i>Sulphides and Sulpho-Salts</i>		60
Pyrite		60
Mispickel		62
Bournonite		62
Tetrahedrite and Tennantite		64

## CASE IV.—DIVISION 2.

MINERALS OF CORNWALL AND DEVON— <i>Continued</i>		
<i>Ores of Iron, etc.</i>		65
Magnetite		65
Hæmatite		67
Göthite and Limonite		68
Chalybite		69
Vivianite		70
Ludlamite, etc.		71
Childrenite		71
Pharmacosiderite		72
Scorodite, etc.		73
Cronstedtite		73

## CASE V.—DIVISION 1.

MINERALS OF CORNWALL AND DEVON— <i>Continued.</i>		
<i>Minerals of the Rarer Metals</i>		75
Nickel and Cobalt Minerals		75
Manganese Minerals		76



CASE V.—DIVISION 1—*Continued.*

MINERALS OF CORNWALL AND DEVON— <i>Continued.</i>		PAGE
Manganite, etc.	.	77
Dialogite, etc.	.	77
Bismuth Minerals	.	78
Pitchblende	.	79
Uranite	.	81
Churchite	.	83

## CASE V.—DIVISION 2.

MINERALS OF CORNWALL AND DEVON—*Continued.*

<i>The Spars of the Mineral Veins</i>	.	84
Fluorite	.	85

## CASE VI.—DIVISION 1.

MINERALS OF CORNWALL AND DEVON—*Continued.*

<i>The Spars—Continued</i>	.	90
Quartz	.	90
Calcite	.	93
Dolomite	.	94
Barytes	.	95

## CASE VI.—DIVISION 2.

MINERALS OF CORNWALL AND DEVON—*Continued.*

<i>Miscellaneous Minerals</i>	.	95
Chalcedony	.	96
Calcite	.	98
Wavellite	.	98
Felspars, etc.	.	99
Garnets, etc.	.	100
Serpentine, etc.	.	102
Allophane, etc.	.	103
Pigotite	.	104
Retinite	.	104

## CASE VII.—DIVISION I.

## MINERALS OF SOMERSETSHIRE, WALES, ETC.

<i>Minerals of West Somersetshire</i>	.	105
<i>Minerals of the Mendips</i>	.	107
Lead Ores	.	107
Mendipite	.	107
Zinc Ores	.	109
Iron Ores	.	110
Potato-stones	.	111

CASE VII.—DIVISION 1—*Continued.*MINERALS OF SOMERSETSHIRE, WALES, ETC.—*Continued.**Minerals of the Bristol District.*

	PAGE
Iron Ores, etc. . . . .	112
Celestite . . . . .	113
<i>Minerals of the Forest of Dean</i> . . . . .	116
<i>Minerals of South Wales</i> . . . . .	117
Millerite . . . . .	120
Hatchettine . . . . .	121
<i>Minerals of Mid Wales</i> . . . . .	121
<i>Minerals of North Wales</i> . . . . .	123
Lead and Zinc Ores, etc . . . . .	123
Manganese Ores . . . . .	125
Copper Ores . . . . .	126
Anglesite . . . . .	127
Brookite, etc. . . . .	128
Gold . . . . .	129

## CASE VII.—DIVISION 2.

## MINERALS OF DERBYSHIRE.

<i>The Spars, etc.</i> . . . . .	131
Calcite . . . . .	132
Elaterite . . . . .	134
Fluorite . . . . .	135
Barytes . . . . .	135
Quartz . . . . .	136

## CASE VIII.—DIVISION 1.

MINERALS OF DERBYSHIRE—*Continued.*

<i>The Ores</i> . . . . .	137
Galena . . . . .	137
Cerussite . . . . .	138
Anglesite, etc. . . . .	139
Matlockite and Phosgenite or Cromfordite . . . . .	139
Zinc Blende . . . . .	140
Calamine, etc. . . . .	141
<i>Minerals from Ecton</i> . . . . .	142

## CASE VIII.—DIVISION 2.

## MINERALS OF W. CUMBERLAND AND N. LANCASHIRE.

<i>Hæmatite Deposits</i> . . . . .	143
Hæmatite, etc. . . . .	144
Quartz . . . . .	148
Calcite, etc. . . . .	149
Aragonite . . . . .	149
Barytes, etc. . . . .	151

## CASE IX.—DIVISION 1.

## MINERALS OF CUMBERLAND.

	PAGE
<i>Minerals of the Caldbeck Fells and the Lake District</i>	152
Apatite . . . . .	153
Wolfram and Scheelite . . . . .	153
Molybdenite . . . . .	154
Grünlingite . . . . .	154
Pyromorphite, etc. . . . .	155
Cerussite, Anglesite, and Linarite . . . . .	157
Malachite, Brochantite, etc. . . . .	157
Hemimorphite . . . . .	158
Tourmaline, Garnet, etc. . . . .	159
Graphite . . . . .	159

## CASE IX.—DIVISION 2.

## MINERALS OF THE NORTHERN LEAD DISTRICTS.

<i>Ores of Lead and Zinc, Barytes, etc.</i> . . . .	161
Galena . . . . .	162
Cerussite . . . . .	165
Zinc Blende . . . . .	165
Calamine, etc. . . . .	166
Chalybite, Pyrite, etc. . . . .	167
Barytes . . . . .	168

## CASE X.—DIVISION 1.

MINERALS OF THE NORTHERN LEAD DISTRICTS—*Continued.**Spars, other than Heavy Spar.*

Witherite. . . . .	170
Bromlite and Barytocalcite . . . . .	171
Calcite and Aragonite . . . . .	172

## CASE X.—DIVISION 2.

MINERALS OF THE NORTHERN LEAD DISTRICTS—*Continued.*

<i>The Spars—Continued</i> . . . . .	174
Fluorite . . . . .	174
Quartz . . . . .	176

MINERALS OF SHROPSHIRE . . . . .	177
----------------------------------	-----

MINERALS OF LEICESTERSHIRE . . . . .	178
--------------------------------------	-----

## CASE XI.—DIVISION 1.

## MINERALS OF THE NEOZOIC STRATA.

<i>Chiefly from the Midlands and S.E. England</i> . . . . .	180
Halite, or Rock-salt . . . . .	181
Gypsum . . . . .	182
Anhydrite . . . . .	185
Celestite . . . . .	186



CASE XI.—DIVISION 1—*Continued.*

MINERALS OF THE NEOZOIC STRATA— <i>Continued.</i>	PAGE
Barytes . . . . .	186
Copper Ores, etc. . . . .	189
Iron Ores . . . . .	191
Glauconite . . . . .	195
Pyrite . . . . .	196
Marcasite . . . . .	198
Quartz . . . . .	199
Allophane . . . . .	200
Aluminite or Websterite . . . . .	201
Calcite . . . . .	201
Jet and Amber . . . . .	202
Copaline, etc. . . . .	203

## CASE XI.—DIVISION 2.

## MINERALS OF SCOTLAND.

<i>Minerals of the Leadhills District</i> . . . . .	205
<i>Minerals of Strontian</i> . . . . .	210

## CASE XII.—DIVISION 1.

MINERALS OF SCOTLAND—*Continued.*

<i>Minerals of the Midland Valley</i> . . . . .	213
<i>Minerals of the Highlands</i> . . . . .	219
<i>Minerals of the Western Isles, etc.</i> . . . . .	221

## CASE XII.—DIVISION 2.

## MINERALS OF IRELAND.

<i>Minerals of Leinster</i> . . . . .	222
<i>Minerals of Connaught</i> . . . . .	226
<i>Minerals of Ulster</i> . . . . .	227
<i>Minerals of Munster</i> . . . . .	231
MINERALS OF THE ISLE OF MAN . . . . .	232

INDEX . . . . .	235
-----------------	-----



# A HANDBOOK

TO A

## COLLECTION OF BRITISH MINERALS.

---

### INTRODUCTION.

Ever since the foundation of the Museum of Practical Geology, a collection of the metal-bearing minerals of the British Islands has formed an important feature in this institution. In this Collection the ores of each metal have been grouped together so that a visitor interested, for example, in the mining of copper-ores, or in the industrial applications of copper, finds all the copper-ores of the country represented in one compact section. The advantages of this simple arrangement have been frequently acknowledged by students of mining and metallurgy. With regard, however, to those minerals which do not contain the common or heavy metals, and which are therefore sometimes loosely termed "non-metallic," no attempt had, until recently, been made to separate the British from the foreign specimens. Yet the separation seemed for many reasons desirable. In an institution intended primarily to illustrate the geology of the British Islands there should undoubtedly be exhibited a collection, as complete as possible, of the mineral productions of the country. Such a collection, though very far from complete, has been recently formed; and this collection it is the purpose of the present Handbook to describe.

The Museum of Practical Geology has long possessed, through its relation with the Geological Survey, an unrivalled collection of British rocks; it also possesses a stratigraphical collection of British Fossils, which, in certain respects, is without parallel elsewhere; and now, by the addition of a special collection of British Minerals, supplementing the fine mineralogical collections already exhibited, the institution has become a fairly faithful exponent of all departments of science bearing on British Geology.

The collection of British minerals, numbering about 1,700 specimens, is installed in a series of twelve double table-cases, placed on the Principal Floor of the museum. The restriction of the collection within these limits is due rather to the want of additional space than to any lack of material. By far the greater number of the



specimens here exhibited have been selected from the valuable cabinets bequeathed to the institution by Henry Ludlam, Esq.; but, where necessary, the Ludlam minerals have been supplemented by specimens selected from other departments of the museum. Yet the impoverishment of the general collections has been but slight, and the fine series of British Ores, which has always been a special feature in the museum, is still practically intact.\* It may be noted that the specimens in this older series are mostly of large size, many being massive examples of ore admirably fitted for display in a public museum, whereas the specimens in the new collection, having been derived mainly from a private cabinet, are comparatively small in size.

In arranging this newly-formed collection of local minerals, it has not been considered expedient to follow any of the ordinary systems of classification, based on chemical composition. On the contrary, it has been felt that the wants of the student of geology, and to a less extent those of many students of mining, might be best met by an arrangement which is fundamentally topographical. No doubt a local arrangement leads to some unavoidable overlap, similar minerals occurring in different localities; but this inconvenience is amply compensated in other ways. By bringing together all the minerals of a particular region, so as to illustrate their natural association, some light may be thrown upon the conditions of their formation. After all, it is the origin of minerals that is philosophically the fundamental feature of interest about them. The specimens have consequently been selected not so much for their perfection of crystallisation—though this, of course, has not been overlooked—as with a special view of illustrating their paragenetic relations and their mode of occurrence in the rocks.

Sowerby, writing as far back as 1811, remarked that “the various circumstances which attend a mineral are very convenient to be known.”† It is these attendant circumstances that have received special attention in selecting the specimens to form this British collection, and in preparing this Handbook.

Although the mode of occurrence of the several minerals and their geological relations have been specially insisted on in this work, it has yet been deemed desirable that the economic aspect of mineralogy should not be altogether neglected. Brief reference has consequently been made, wherever possible, to the industrial applications of the minerals of the British Islands.

It should be explained that this Handbook has been prepared with a two-fold object. Primarily it is intended for the use of visitors, who, without any special acquaintance with mineralogy,

---

\* The specimens which do not belong to the Ludlam collection are indicated by a red disc on each of their labels.

† “British Mineralogy.” By James Sowerby. London: 1811, vol. iv., p. 174.



may desire to learn something about the Collection of British Minerals. Experience has shown that an intelligent visitor on seeing a specimen is apt to ask about it these questions : 1. What is it ? 2. Where does it come from ? 3. How has it been formed ? 4. What is its use ? An endeavour is consequently made in this guide-book to give simple answers to such enquiries.

In order that the work may be self-interpreting, most of the technical terms, which are necessarily used in the description of minerals, receive brief explanation. It has not, however, been considered necessary to explain ordinary chemical expressions, since these are now generally understood. In endeavouring to answer questions relating to the origin of minerals, much difficulty is encountered ; for in the present state of our knowledge, notwithstanding all that has been written, it rarely happens that a mineralogist can speak with certainty as to the way in which a given mineral has been formed. Still, an attempt has been made in these pages—though generally but a brief and vague attempt—to meet, if not to satisfy, enquiry on this subject ; and this has led to the occasional introduction of matter of a rather speculative character.

Whilst this Handbook is thus intended to serve the purpose of the ordinary visitor to the Museum, it is believed that it may also prove serviceable to many students of geology and of mining. It is principally for their use that copious references to original authorities have been introduced, in the shape of foot-notes. Such references would be useless, not to say pedantic, in a popular guide-book, but they become invaluable in a work likely to be used by serious students.

In the preparation of this Handbook the ordinary sources of mineralogical information have been consulted, but special acknowledgment should be made of the elegant volume of Professor Miers,\* the classical work of the Danas,† and the elaborate treatise of Dr. Hintze.‡ For British mineralogy the standard work of Greg and Lettsom§ has naturally been used with freedom. In that work, written nearly half a century ago, the number of mineral species occurring in the British Islands is given as 241. Since that time many others have been added, and a Supplementary List was

\* “Mineralogy, an Introduction to the Scientific Study of Minerals.” By Henry A. Miers, D.Sc., M.A., F.R.S. 1902.

† “The System of Mineralogy of James Dwight Dana: Descriptive Mineralogy.” 6 ed. By Edward Salisbury Dana. New York. 1896.

‡ “Handbuch der Mineralogie.” von Dr. Carl Hintze. Leipzig. (*In Progress.*)

§ “Manual of the Mineralogy of Great Britain and Ireland.” By Robert Phillips Greg, F.G.S., and William G. Lettsom. London. 1858.

It may be mentioned here that several papers on “The Mineral Topography of Great Britain” were contributed by A. W. Tooke, M.A., F.G.S., to the *Mining Review*, commencing in 1836.

contributed by Mr. L. J. Spencer to the British Association in 1898.\* According to this authority the number of species known in Great Britain and Ireland at that date was 293. It must not be supposed, however, that representatives of all these species are to be found in this Collection.

In closing this introductory chapter, the writer is anxious to acknowledge the assistance which he has received in the preparation of this work from his former colleagues of the Geological Survey and Museum—especially from Mr. Horace B. Woodward, F.R.S., Mr. Clement Reid, F.R.S., and Mr. Aubrey Strahan, F.R.S.

---

\* "Supplementary List of British Minerals." By L. J. Spencer, M.A., F.G.S. *Report of British Association*, Bristol meeting, 1898, p. 875. Also, *Geological Magazine*, New Series, Dec. 4. Vol. vi. (1899) p. 75.



## CASE I.

## DIVISION 1.

## THE MINERALS OF CORNWALL AND DEVON.

## CASSITERITE AND ITS ASSOCIATES.

(Nos. 1 to 68.)

In a topographical arrangement of a collection of British minerals it seems desirable, for several reasons, to start with the south-western peninsula. No part of Britain of equal extent has yielded a greater number or a richer variety of minerals, whilst the extensive mining operations carried on for so long a period in this area have afforded exceptional facilities for studying the natural conditions under which the minerals occur.\*

It has not been considered desirable to separate the minerals of Cornwall from those of Devon. The River Tamar, though forming for the most part a convenient dividing line between two counties, can in no sense be regarded as marking a geological boundary. East Cornwall and West Devon are united by structural homogeneity. Indeed, all Cornwall and though not all Devonshire, at least that part which includes Dartmoor and the country to the west may be regarded as forming a single geological area.

In a catalogue of Cornish minerals contributed many years ago to the Royal Geological Society of Cornwall,† by the late Mr. John Garby, an enthusiastic local collector, something like 150 species and varieties were enumerated as occurring in Cornwall. But even this number was much increased by Mr. J. H. Collins, when he published in 1871, his "Handbook to the Mineralogy of Cornwall and Devon."‡

\* Becher, an old German mineralogist, writing at Truro in the seventeenth century, says (or rather, is made to say by his translator), "The earth is here so abundant in different kind of fossils that I believe there is no place in the world which excels Cornwall in the quantity and variety of them; and I confess I have found here a mining-school." Quoted in "Observations relative to the Mineralogical and Chemical History of the Fossils of Cornwall." By Martin Henry Klaproth. Translated by John Gottlieb Groeschke. London, 1787, p. ii. The term "fossil," used in this quotation and in the title was formerly employed in its wide sense to include minerals as well as organic remains, and, in fact, literally anything "dug up."

† "A Catalogue of Minerals found in Cornwall, with their Localities." By John Garby, Esq., *Trans. Roy. Geol. Soc. Cornwall*, vol. vii. (1865) p. 72.

‡ A Handbook to the Mineralogy of Cornwall and Devon." By J. H. Collins, F.G.S. Truro and London, 1871.

So far as Devonshire is concerned, the late Mr. Townshend M. Hall contributed a paper "On the Mineral Localities of Devonshire" to the Devonshire Association in 1868. See *Trans. Dev. Assoc.*, vol. ii., Part ii. (1868) p. 332; and *addenda* in vol. iii. (1869), p. 76. The late Mr. F. Rutley gave a list of minerals from the neighbourhood of Tavistock in the Geological Survey Memoir on Brent Tor (1878) p. 50.



Although the south-western peninsula has thus yielded so great a diversity of minerals, and these frequently of such beauty as to justify its description as "the natural mineral cabinet of Britain," it must not be supposed that fine specimens, such as are here exhibited, are now to be readily obtained from this part of the country. Not only is the mining industry of Cornwall and Devon much less active than formerly, but the older mines now working are not prolific in cabinet specimens of crystallised minerals. It was observed by the late Mr. W. Jory Henwood, a distinguished authority on the mines and minerals of Cornwall, that crystals are far more numerous near the surface than at great depths.\* It is in the shallow workings, within range of meteoric influences, that we naturally expect to find most of those beautiful oxides, carbonates, phosphates, arsenates and other oxidised products for which old Cornish collections are celebrated. The collection here exhibited is particularly rich in fine examples of such minerals. Many of the important specimens in the Ludlam collection were obtained from the famous Turner collection formed by Heuland in the early years of the last century;† whilst others were purchased, thirty or forty years ago, from the late Mr. Richard Talling, an intelligent collector of Cornish minerals, at Lostwithiel. At the present time it is practically impossible to procure such specimens, except from old collections.

Most of the minerals of Cornwall and Devon here exhibited have been obtained from mineral-veins, or *lodes*. The crystals are frequently found studding the walls of cavities in the veinstone, such cavities being known as *vugs* or *voughs*. The veins are irregular sheet-like masses of mineral matter, varying in length, in thickness or width, and in depth. Usually they are highly inclined, and in some cases stand in a position nearly vertical.‡ Whilst some veins consist of mineral matter which has been deposited in pre-existing

---

\* "Observations on the Metalliferous Deposits of Cornwall." By W. Jory Henwood, F.R.S. "Reprinted with alterations and additions" from *Journ. Roy. Inst. Cornwall*, vol. iv., No. xiii. (1872), p. 8 of reprint. Also *Trans. Roy. Geol. Soc. Corn.*, vol. v. (1843), p. 206.

† These minerals are described in Lévy's catalogue: "Description d'une collection de Minéraux, formée par M. Henri Heuland, et appartenant à M. Ch. Hampden Turner." Par A. Lévy, 3 vols. and Atlas. London: 1837. In this work the localities of the British specimens are often given very vaguely and the Cornish minerals are generally referred simply to "Cornouailles." Such lack of definite location is not, however, restricted to these specimens. When minerals are purchased from local dealers there is often not unnaturally some reticence with regard to the exact mine, or other source, from which a specimen may have been obtained. Probably, the dealer himself does not know precisely, since it is to the interest of a person who finds the mineral to guard his own knowledge of the locality with some jealousy. Many of the old Cornish specimens were obtained surreptitiously by the miners, and it was a matter of importance to them that the discovery should not come to the knowledge of the captain of the mine, or of any of the adventurers. To the geologist this want of exact information as to locality is a serious loss.

‡ The inclination to a vertical plane is called the *hade* or *underlie* of the lode, and that to a horizontal plane the *dip*.

fissures in the rocks, others appear to be bands, or sheets, of altered rock, impregnated with certain metal-bearing minerals. Many of the Cornish tin-lodes belong to the latter class, as pointed out by the late Sir Clement Le Neve Foster.\* The rock in the immediate neighbourhood of the lode is known to miners as the "*country*." In Cornwall and Devon it usually consists either of granite, or of the slaty rocks termed *killas*, or of some of the igneous rocks, like quartz-porphyry, that pass under the general name of *elvan*.†

The course, or *strike*, of the lodes which carry tin and copper-ores in the West of England, though varying considerably in different districts, may be said to be generally north of east and south of west. Their direction is, therefore, roughly parallel to the general trend of the south-western peninsula; nor does it differ greatly from that of the series of large granitic bosses which stretch from Dartmoor to the Land's End. In addition to these tin and copper-lodes, there is a later set of veins, or *cross-courses*, running roughly in a north and south direction, and frequently carrying ores of lead and zinc (p.54).‡

The minerals of Cornwall and Devon occupy the whole of Cases I to VI in this collection. Each case consists of two parts, recognised as *Divisions* 1 and 2. Case I. is devoted to the exhibition of a series of specimens, illustrating the characters of *Cassiterite*, the common ore of tin, its associated minerals, and its mode of occurrence.

*Native Tin*, or tin occurring naturally in a metallic state, though not unknown, is a substance of extreme rarity. Even when it has been recorded, doubt has not unfrequently been raised as to its authenticity; and specimens from Cornwall, regarded formerly as native tin, are now generally believed to be nothing more than smelted products from ancient workings, known locally as "*Jews'-house tin*."§

Tin is found in nature almost invariably as an oxide. It is true that it is known also as a sulphide, which, in association with copper and iron sulphides, forms the mineral termed *stannite* (No. 68, p.20), but this is a substance quite local and exceptional in its occurrence. Practically all our tin-ore is tin oxide. This mineral—the native

\* For a modern description of lodes consult "A text-book of Ore and Stone Mining." By C. Le Neve Foster, B.A., D.Sc., F.R.S., 3rd ed., 1900, p. 5: also "A Treatise on Ore Deposits." By J. Arthur Phillips, F.R.S., 2nd. ed. by Henry Louis, M.A., 1896. See also Sir Archibald Geikie's "Text-book of Geology," 4 ed., 1903, p. 807.

† The geology of Cornwall is described in the earliest of the memoirs of the Geological Survey. "Report on the Geology of Cornwall, Devon and West Somerset." By Henry T. De la Beche, F.R.S., etc. 1839.

‡ The *Trans. Roy. Geol. Soc. Cornwall* may be referred to for numerous papers on the mineral veins by Mr. W. J. Henwood, Sir W. W. Smyth, Sir C. Le Neve Foster, Mr. J. H. Collins, Mr. J. B. Hill, Mr. Donald MacAlister and others.

§ On ancient ingots of tin and on the old smelting works called *Jews' Houses* see Mr. Henwood's paper in *Journ. Roy. Inst. Corn.*, vol. iv. (1873.) p. 249.



dioxide, or stannic oxide,  $\text{Sn O}_2$ —is known to the mineralogist as *Cassiterite* and to the miner as *tinestone*, or simply “*tin*.”\*

Although tin can hardly be described as a rare metal, its ores are rather restricted in geographical distribution. Cornwall is one of the oldest and best known, and geologically one of the most typical, tin-bearing countries of the world.

The remarkable discovery that copper, a comparatively soft metal, could be rendered fit for the production of cutting instruments with a hard and keen edge, by the addition of about ten per cent. of tin led to the early recognition of the exceptional value of the white metal. For the production of this alloy Cornwall supplied tin to some of the early centres of civilisation in the Mediterranean, probably as far back as the so-called Bronze Age. It has sometimes been supposed that this part of the world was known as the “*Cassiterides*,” or “*Tin Islands*”—a view supported recently by M. Salomon Reinach.†

At the present day, after having supplied tin for perhaps thirty centuries, Cornwall remains the most important tin-producing centre in Europe: indeed, with the single exception of “the Straits,” it stands at the head of all the tin countries of the world.‡ According to the official statistics issued by the Home Office, the amount of dressed tin-ore obtained in Cornwall during the year 1902 was 7,552 tons, 3 cwts. valued at £513,303.§ It is notable that of this amount as much as 1,828 tons, or nearly one-quarter of the total output, came from the single mine of Dolcoath—a mine which is at once the deepest and the most productive in the county. The lodes worked at this mine were originally in killas and yielded copper-ore, but

---

\* Although it is not deemed necessary in this Handbook to enter into details with regard to the origin and meaning of mineral names, it seems desirable to point out with regard to tin-stone, perhaps the most interesting and characteristic of all British minerals, that the mineralogical name is taken from *κασσίτερος* (*Kassiteros*), the Greek word for tin. Some philologists have held that the connection of this word with the Sanskrit *kastira* suggests that the earliest tin must have been brought to Europe from the East, perhaps from Khorassan or from the famous tin-producing localities of Malacca and Banca. Recently, however, it has been suggested that *κασσίτερος* may have been derived from a Keltic source. (M. d'Arbois de Jubainville, *Les Celtes*.)

The old Cornish word for tin was *stean*. According to Beckmann the word *stannum* came to be definitely applied to tin in the fourth century. The *stannum* of Pliny was a pewter-like alloy, whilst tin was known to some Roman writers as *plumbum album* or *white lead*. Metallic tin is still known in this country as *white tin*, to distinguish it from *black tin*, which is the term applied to the dressed ore.

† The reader will find the classical references to Britain conveniently collected and translated in the folio work: *Monumenta Historica Britannica*. 1848. For information on prehistoric bronze, see Sir John Evans's “Ancient Bronze Implements” (London, 1881) and the British Museum “Guide to the Antiquities of the Bronze Age” (1904). In discussing the source of tin for early bronze-making, the occurrence of tin-ores in Tuscany must not be overlooked.

‡ Rothwell's “Mineral Industry.” Vol. xi. (1903). p. 586.

§ “Mines and Quarries: General Report and Statistics for 1902.” Edited by C. Le Neve Foster, D.Sc., F.R.S. (1903), p. 276.



passing downwards they entered granite, and then, as often observed elsewhere in the West of England, the copper gradually gave way to tin.

Observations in many parts of the world have shown that there exists between the occurrence of tin-ore and the presence of granite, or rocks of similar type, so constant a relationship as to suggest a causal connection. Whether in Cornwall or in Saxony and Bohemia, in France or in Spain, in the Malay Peninsula or in New South Wales, not to mention other localities, the occurrence of cassiterite seems to have been determined by the intrusion of an acid magma. Moreover in all these localities the cassiterite is associated with a peculiar group of minerals characterised by the presence of fluorine, and—in a less marked degree—boron, phosphorus and arsenic.

As far back as 1841 M. Daubrée, struck with this relationship, suggested that the tin had been brought up from plutonic sources in the form of a volatile fluoride.\* This seems to have been the first occasion on which attention was directed to the function of fluorine as an important mineralising agent whereby the metal could be carried from deep-seated sources into mineral-veins.† Daubrée's views were taken up by Élie de Beaumont in his lectures at the Collège de France, and elaborated in his famous paper on volcanic and metalliferous exhalations.‡

Subsequently Daubrée carried out his classical experiments on the artificial production of cassiterite by the reaction of water-vapour on tin fluoride, or rather chloride.§ This synthesis conclusively demonstrated the possibility of what had previously been only a feasible conjecture as to the manner in which oxide of tin might have been formed in nature. As a matter of convenience Daubrée used the chloride instead of the fluoride; but the halogens, chlorine and fluorine, are so closely related as mineralising agents that the substitution was perfectly allowable. It is clear, however, that in the natural formation of tinstone fluorine was the prime agent, since in nearly all cases, there are certain fluorine-bearing minerals which form a group of satellites around the tin-ore.

Although Daubrée has the merit of having been the first to suggest the relation of fluorine to the genesis of tin-stone, the influence of

\* "Memoire sur le gisement, la constitution et l'origine des amas de minerai d'étain." *Annales des Mines*, 3e série, tome xx. (1841) p. 65. A committee of reference, reporting on a paper presented to the Academy of Sciences in 1841, said: "M. Daubrée est le premier, qui ait donné au fluor une puissance pour ainsi dire créatrice." *Comptes Rendus*, tome xiii. (1841), p. 834.

† The term "mineralising agents," or mineralisers, is given, following the French school, to those bodies which render others volatile, or promote crystallization, without entering into the composition of the final product.

‡ "Note sur les émanations volcaniques et métallifères." *Bulletin de la Société Géologique de France*. 2e série, tome iv. (1847), p. 1249.

§ "Recherches sur la production artificielle de quelques espèces minérales cristallines, particulièrement de l'oxyde d'étain, de l'oxyde de titane et du quartz." *Annales des Mines*, 4e série, tome xvi. (1849), p. 29. See also Daubrée's "Études synthétiques de Géologie expérimentale," 1879, p. 37.

this element as a subterranean agent in the alteration of felspar-bearing rocks had been recognised as early as 1824 by Leopold von Buch. In order to account for the formation of certain deposits of kaolin near Halle, this geologist invoked the aid of hydrofluoric acid, and supported his suggestion by pointing to the abundance of fluor spar in the decomposed rock.\* In like manner fluor spar and other fluorine-bearing minerals occur in the altered granite in Cornwall, suggesting that here also fluorine may have been responsible for the alteration. This view is supported by Mr. J. H. Collins, who, in describing the Hensbarrow granite, refers to the constant presence of minerals containing fluorine in the china-clay districts.† Mr. Clement Reid's study of the granites of Western Cornwall led him to conclude that the masses of china-stone, or kaolinised rock, which have very local distribution superficially but great downward extension, may represent pipes up which fluoric and boracic vapours escaped.‡ It seems, therefore, probable that in certain cases, perhaps in many, kaolinisation may have proceeded from below upwards, and that the agent of alteration may have been some compound of fluorine, either in solution or as a solfataric exhalation. Such alteration of granite at one locality obviously does not preclude other means of alteration elsewhere; and the commonly accepted view, based on the researches of Forchhammer and of Bischof, that kaolin has been formed by the alteration of felspar through the action of meteoric waters containing carbonic acid, still admits of local application.

With regard to the stanniferous deposits in Cornwall it may be pointed out that Dr. Richard Pearce, now of Denver, suggested as far back as 1864 that many of the Cornish tin-lodes, so far from being mineral deposits in definite fissures, were simply masses of altered granite, more or less impregnated with tin-ore.§ This view has been ably developed by Sir C. Le Neve Foster, who has shown that such important ore-deposits as the Great Flat Lode, near Carn Brea, are of this nature.|| The greater part of this lode is an ill-defined band of tin-bearing schorl-rock, adjacent to a thin quartzose vein, called the *leader*, which represents a narrow fissure filled with brecciated veinstone. This crack, or joint, may have served as a channel for the ascent of vapours or solutions, which acting on the neighbouring rock, whether granite or killas, might effect its alteration, with development of schorl and deposition of cassiterite.

\* *Min. Taschenbuch*, 1824, p. 437. *Gesammelte Schriften*, vol. iii. (1877), p. 186.

† "The Hensbarrow Granite District." By J. H. Collins, F.G.S., Truro: 1878, p. 36.

‡ "Summary of Progress of Geological Survey for 1901" (1902), p. 26.

§ "The Influence of Lodes on Rocks." *Rep. Miners' Assoc. Cornwall*. Truro: 1864, p. 18.

|| "On the Great Flat Lode south of Redruth and Camborne, and on some other tin deposits formed by the alteration of Granite." By C. Le Neve Foster, B.A., D.Sc., F.G.S. *Quart. Journ. Geol. Soc.*, vol. xxxiv. (1878), p. 640.



The band of altered rock immediately adjacent to the vein is usually called in Cornwall a *capel*, but there is a gradual transition between the lode and the capel on the one hand, and on the other between the capel and the unaltered "country."\*

Similar alteration of granite, with formation of tin-lodes, was described by Sir C. Le Neve Foster as occurring at East Wheal Lovell and at some other Cornish localities.† At Cligga Head, near St. Agnes, the granite in the vicinity of the tin-bearing quartz veins has been converted into *greisen*—a granular quartz-mica rock, usually carrying topaz—which is commonly associated with the tin-deposits of Saxony. The formation of greisen at Cligga Head has been recently studied in detail by Mr. J. B. Scrivenor,‡ who shows that the felspar of the granite has been partly converted into muscovite, quartz and topaz, and the biotite into brown tourmaline, magnetite and quartz. In the centre of each band of greisen is a quartz vein representing the narrow fissure from which the alteration proceeded, and containing cassiterite, wolfram, mispickel, copper pyrites and blue tourmaline: it is, in fact, a miniature tin- and copper-lode.

It seems well established that the occurrence of tin ore in Cornwall, as in most other countries, is connected (1) with the presence of an acid eruptive rock, (2) with the profound alteration of this rock, and (3) with the association of a peculiar assemblage of minerals, suggesting the nature of the medium by which the alteration may have been effected. The precise details of the processes whereby the ore has been formed and introduced into the veins, are still, however, not free from obscurity.

Most of the Cornish lodes yield ores of both tin and copper; and it appears that these heavy metals must have been derived originally from the acid magma. Probably the tin was carried off in association with fluorine, and the copper with sulphur. The vapour extracted from the eruptive magma, judging from the minerals occurring in the lodes, must have contained such elements as fluorine, boron, phosphorous, arsenic and sulphur. While the emanations were at a temperature above their "critical point,"§ and therefore in a vaporous condition, they would produce in the rocks through which they rose that kind of alteration termed *pneumatolytic*. This action has been carefully studied by Prof. J. H. L. Vogt, of Christiania, who in recent years has devoted much attention to the genesis of

\* On capels consult Mr. J. H. Collins's paper "On some Cornish Tin-stones and Tin-capels." *Min. Mag.*, vol. iv. (1880), pp. 1, 103; vol. v. (1884), p. 121.

† "Remarks upon the tin-deposits of East Wheal Lovell." *Trans. Roy. Geol. Soc. Cornwall*, vol. ix., part ii. (1876), p. 167; and "Remarks on some Tin Lodes in the St. Agnes District." *Ibid.*, vol. ix., part iii. (1876), p. 205.

‡ "The Granite and Greisen of Cligga Head (Western Cornwall)." By John Brooke Scrivenor, M.A., F.G.S. *Quart. Journ. Geol. Soc.*, vol. lix. (1903), p. 142.

§ The *critical point* is that temperature above which the given substance remains permanently gaseous, whatever the pressure.



ore-deposits, and who is led to believe that the formation of the tin-lodes probably commenced before the complete cooling of the granite.\*

In the tin-bearing districts of the Erzgebirge, or "Ore mountains," between Saxony and Bohemia, where the Cornish conditions are closely paralleled, the alteration of the granite and the impregnation of the rocks with tin-ore have been repeatedly studied by eminent geologists and mining engineers. According to Dr. Karl Dalmer, one of the latest and highest authorities, the *Zwitter* of Altenberg—which is an altered granite containing tinstone—has resulted from changes which took place after its solidification, but probably while the deeper part of the granite was still in a glowing condition, so that the vapours which affected the upper portion may have arisen from the lower part even before complete consolidation of the magma.†

Although the formation of the tinstone in Cornwall and Devon may have been initiated during an early phase of the granitic intrusion, while the plutonic mass if not molten was yet at a temperature so elevated as to throw off highly heated vapours, it appears likely that the deposition of the ore in its present position was effected, partly at least, by the agency of thermal waters. Much of the tin-ore, as we now see it, may be regarded as a deposit from solution rather than as a direct product of the action of vapours.

The action of heated solutions, associated with fumarolic action, has been described by Prof. Vogt as *pneumato-hydato-genetic*. If the tin left the magma as a volatile fluoride under great pressure, the emanations escaping through the rocks would yield soluble matter to the water, which must have been encountered as soon as the physical conditions permitted liquidity. The tin, released from its haloid combination by the action of water, whether vaporous or liquid, would take the form of an oxide, which might be carried away in solution, and ultimately form a deposit in cracks or an impregnation in a rock, in either case constituting, if sufficiently abundant, an ore-body.

It is true that tin dioxide is so sparingly soluble in water that it is not unfrequently regarded as a substance practically insoluble. It was found, however, long ago by Bischof‡ that cassiterite is soluble in water charged with alkaline carbonates—salts which are very common in natural waters. More recently C. Doelter has shown

---

\* For Prof. Vogt's important work the following papers may be consulted.—"Ueber die durch pneumatolytische Processe an Granit gebunden Mineral-Neubildungen." *Zeitschrift für praktische Geologie*, Dec. 1894, p. 458, "Beiträge zur genetischen Classification der durch magmatische Differentiationsprocesse und der durch Pneumatolyse entstanden Erzvorkommen." *Ibid.* April, 1895, p. 145. "Problems in the Geology of Ore-deposits." *Trans. American Institute Mining Engineers*, vol. xxxi. (1902), p. 125.

† "Erläuterungen zur geologischen Spezialkarte des Königreichs Sachsen. Section Altenberg-Zinnwald." Sheet 119. Leipzig: 1890, p. 66. Also: "Der Altenberg-Graupener Zinnerzlagerstättendistrict." *Zeitsch. f. prakt. Geologie*, Aug. 1894, p. 313.

‡ "Lehrbuch der chemischen und physikalischen Geologie," 2nd Ed., vol. iii. (1866), p. 811.

that it is slightly soluble even in distilled water at 80°C., whilst the solubility is increased by the presence of sodium fluoride, though not by sodium chloride.\* Its occurrence in the waters of certain hot springs is inferred from its presence in deposits of siliceous sinter. Thus, M. Errington de la Croix obtained from a warm spring at Ajer Panas, in Selangor, a deposit consisting mainly of opaline silica like geyselite, which was found, on analysis by Prof. Stanislas Meunier, to contain 0.5 per cent. of stannic oxide.† Here, then, is an example of the contemporaneous formation of a tin-bearing deposit.

According to Mr. J. H. Collins, the antlers of the red deer, formerly found rather abundantly in the tin-bearing gravels worked in the Carnon and Pentuan valleys, were partially mineralised with cassiterite. His analysis of a specimen in the museum of the Royal Geological Society of Cornwall showed the presence of 2.6 per cent. of stannic oxide.‡ Mr. R. Q. Crouch, describing a certain specimen, says "the whole horn had undergone a change into tin ore."§ But possibly this may not imply solution of the tinstone.

In certain Cornish mines there have occasionally been found conglomerates and breccias, consisting of fragments of rock broken from the walls of the lode and rolled pebbles washed into the fissure cemented together with cassiterite and other minerals, which have probably been deposited from circulating waters. No. 49 is a specimen of the famous conglomerate from the Relistian mine, in Gwinear, described nearly a century ago by Mr. Joseph Carne,|| in which cassiterite, in a crystallised condition, forms part of the cementing medium. In a brecciated lode occurring at New Rosewarne mine, and described by Sir C. Le Neve Foster, the agglutinating minerals included quartz, cassiterite, mispickel, chlorite and pearl-spar.

Pseudomorphs—or those minerals which by chemical or mechanical alteration assume the crystal forms of other species, so that their substance and structure bear no necessary relation to external form—are in many cases highly suggestive in discussing the origin of minerals. Nos. 47 and 48 are examples of the well-known pseudomorphs of cassiterite after felspar from Wheal Coates,¶ an old tin

\* *Journ. Chem. Soc.*, vol. lviii (1890), p. 1070. *Min. Mit.*, Bd. xi (1890), p. 325.

† "Examen chimique d'eaux minérales provenant de Malaisie; minerais d'étain de formation actuelle." *Comptes Rendus* (27th May, 1890), tome cx., p. 1083.

‡ "Note on the occurrence of stanniferous Deerhorns in the tin-gravels of Cornwall." *Trans. Roy. Geol. Soc. Corn.*, vol. x. (1887), p. 98.

§ "Notice of the occurrence of the Horns and Bones of several species of Deer in the Tin Works of Cornwall." By Richard Q. Crouch, Esq. *Trans. Roy. Geol. Soc. Corn.*, vol. vii. (1865), p. 185.

|| "An account of the Relistian Mine." *Phil. Trans.*, vol. for 1807, p. 293.

¶ The word *Wheal*, denoting a mine, is the usual form in which the old Cornish word *Huel* is now written. The late Mr. Robert Hunt tried in vain to revive the original form. Writing in 1884 he says: "I have constantly employed, since 1847, the term 'Huel' which is undoubtedly the ancient Cornish term—signifying a mine or mineral work—but the corruption 'Wheal' is so undeviatingly used by all, that there is no reason why I should any longer endeavour to bring the older term into use again."—"British Mining." By Robert Hunt, F.R.S. (1884), p. 190.



mine near St. Agnes, where they occurred at one time in great abundance. The crystals present mostly the characteristic form of Carlsbad twins of orthoclase\* ; but while the shape has been faithfully preserved the feldspathic matter itself has disappeared. The replacing material consists largely of cassiterite, usually a granular mixture of cassiterite and quartz. The lode which yielded these remarkable pseudomorphs, which are said to have "occurred in millions," was in a soft decomposed granite, or perhaps an elvan, and contained so much sandy matter that it has been called a "sand lode."† Similar pseudomorphs have been found, though but rarely, at other localities in Cornwall, as at Carn Brea and at Balleswidden, near St. Just. It seems probable that they were formed by the pneumatolytic alteration of a porphyritic rock, after its consolidation but while still in a heated condition. On the other hand, it was contended by Bischof that ordinary carbonated waters, coursing through tin-bearing rocks, might be competent to dissolve feldspar and to deposit tinstone in its place.

The presence of tin has been recorded in certain rock-forming minerals, notably in zinnwaldite, a lithia-mica, where it probably exists as microscopic inclusions of cassiterite. It has even been suggested that in some silicates tin may partially replace silicon, that tin dioxide may play the part of silicon dioxide. It was the presence of the heavy metals in many rock-forming silicates that led the late Prof. F. Sandberger to his well known views on the origin of mineral veins by a process of *lateral secretion*.‡ According to this hypothesis, the neighbouring rocks are to be regarded as the primitive source of the ores, the contents of a mineral vein having been leached out of the surrounding "country."

Although this view received much support, it also encountered much opposition, especially from the late Prof. A. Stelzner, of Freiberg. Admitting that the heavy metals of the ores really exist in some of the minerals of the neighbouring rocks—of which, indeed, there seems no doubt—it remains a matter of discussion as to the direction the migration may have taken place ; whether the tin in the rock has escaped from the vein, or the tin in the vein been drawn from the surrounding rock.

Probably there is some truth in both views. The formation of a mineral-vein is usually so complex a process that there is room for several explanations applicable to different phases of its development. If the tin-ore was originally derived from deep-seated sources by magmatic extraction, it may subsequently have become distributed

\* See Laspeyres, *Zeits. f. Kryst.*, vol. i. (1877), p. 344 ; Kohlmann, *ibid.*, vol. xxiv. (1895), p. 355. "Carlsbad twins" are so called because characteristically seen in the orthoclase-feldspar of the Carlsbad granite.

† In some of the Wheal Coates pseudomorphs, the feldspar has been replaced by kaolin and secondary mica, as seen in No. 48, and in certain specimens in the Case of pseudomorphs and others in the Horse-shoe Case. For British pseudomorphs generally see Prof. Miers in *Min. Mag.*, vol. xi. (1897), p. 263.

‡ "Untersuchungen über Erzgänge." Von Fridolin Sandberger. Wiesbaden. 1882.



by solution ; whilst ore disseminated through a rock as an impregnation may have been dissolved out, transported to a greater or less distance, and segregated locally. The plane of weakness in a rock, represented by a vein, has in most cases been opened again and again, and has been the scene at different stages of very varied activities. Dr. Flett has recently shown how complicated must have been the history of certain brecciated veinstones in Cornwall.\*

*Cassiterite.* (Nos. 1 to 67.)

The specimens numbered 1 to 67, exhibited in the first division of Case 1, are (with the exception of No. 46) examples of Cornish *Cassiterite* or tinstone. The crystals from Cornwall are usually small, but some of exceptional size are here exhibited, and others will be found among the British ores in Wall-cases 7 and 8.

Cassiterite crystallises in the *tetragonal* system, termed by some writers the pyramidal, dimetric or quadratic system.† The specimen No. 1 shows short four-sided prisms, each terminated by a four-faced pyramid ; but crystals of such simple type are not common. Many, if not most, of the crystals exhibited in this case are twinned, or maced, sometimes exhibiting geniculate or knee-shaped structures. Small paper arrows on No. 6 point to the re-entrant angles so characteristic of twinned crystals, and many similar, if less conspicuous, angles may be observed on other specimens.‡

Nearly a century ago, a large series of fine crystals of Cornish tinstone was examined by William Phillips, and described and figured by him in an early volume of the "Transactions of the Geological Society of London."§ His observations enabled him to trace a local distribution of particular types of crystals.

The colour of cassiterite, as shown by the specimens in this case, is frequently a rich chestnut-brown, passing into a brilliant black. It is generally said that the dark colour is due to the presence of ferric oxide. Zonal colouration is sometimes seen in microscopic sections of crystals of cassiterite. In Nos. 19 and 20 the crystals are translucent and of a red colour, rather like some kinds of ferruginous quartz ; but such crystals are rare. A yellowish brown tinstone, somewhat

\* Geol. Surv. Summary of Progress for 1902 (1903), p. 154.

† Crystals are classified, according to their geometrical and physical characters, in large groups called *systems*. Within these systems there are smaller groups, based on certain types of symmetry, called *classes*. Six natural systems are recognised, and thirty-two classes are possible. For modern views on crystals the student may consult Prof. N. Story-Maskelyne's "Crystallography" (Oxford: 1895), and Prof. W. J. Lewis's "Treatise on Crystallography" (Cambridge: 1899). See also Prof. Miers's "Mineralogy" (London: 1902).

‡ A re-entrant angle is one exceeding  $180^\circ$ , or greater than two right angles.

§ "A Description of the Oxyd of Tin." By William Phillips, *Trans. Geol. Soc.*, vol. ii. (1814), 336. Cornish cassiterite has since been the subject of crystallographical study by Prof. Becke (*Min. Mit.*, 1877, p. 243), Dr. Kohlmann (*Zeits. f. Kryst.*, vol. xxiv., 1895, p. 350), and others.

translucent, is called *rosin-tin*. In connection with the colour of cassiterite, attention may be directed to some white tinstone from the Malay Peninsula presented by Cecil Wray, Esq., and exhibited in Wall-case 40; whilst among the Australian minerals in Wall-case 38 will be found some yellow, brown, and red cassiterite, so transparent as to be cut into gem-stones, which display diamond-like brilliancy. The adamantine lustre of cassiterite is rather characteristic, and the eye will be attracted by the splendid faces of many of the Cornish crystals.

The variety of cassiterite known as *sparable tin* is represented by Nos. 21 to 32. This variety occurs in sharply-pointed crystals due to a large development of the ditetragonal, or eight-sided pyramid, associated with a slender prism striated vertically. According to Mr. R. H. Solly who has studied this type,\* it occurs chiefly in the Camborne district, always in close proximity to an elvan, and invariably accompanied by chlorite or "peach." The common name is said to have been suggested by the resemblance of the sharp elongated crystals to the sparable nails used by cobblers, the term "sparable" itself being, perhaps, a corruption of "sparrow-bill," in allusion to the shape. Other trivial names are *tooth-tin*, referring to the acute pyramidal terminations (No. 23), and *needle-tin*, applied to the very slender crystals (Nos. 27, 31, etc.).

The fibrous variety of cassiterite known as *wood-tin* is represented by a series of specimens (Nos. 33 to 40.) This mineral was originally found in the form of rolled fragments in the old Cornish workings for stream-tin, and for a long time was known only in this detrital form. Examples of such water-worn fragments, exhibited in the tray No. 34, show the characteristic fibrous structure, the hair-brown colour, and the dull lustre of this variety. Many of these pieces resemble, except in density, the fibrous oxide of iron called "wood-iron ore"; and old writers, struck with the resemblance of the wood-tin to fibrous hæmatite, termed it *tin-hæmatite*.

The small pebbles of concretionary tinstone, No. 43, present a zonal structure, similar to that of an agate, and suggest gradual formation by a sequence of deposits. The agatiform appearance is well seen in the large pebble with a dimpled surface, each pit here representing the position of a former nucleus surrounded by successive rings. Some of the small pebbles in No. 44 show the botryoidal shape of the concretions. In the large water-worn fragment, No. 41, the wood-tin is associated with vein-quartz, suggesting the source of the mineral.

Wood-tin in the matrix is of exceptional occurrence, but several fine examples are here shown. The specimens in Tray No. 33, from the Prideaux Wood mine, near Liskeard, exhibit wedge-shaped segments of globular concretions, composed of radiating fibres with concentric bands of pale and dark brown tints. The mineral is extremely brittle, breaking in the direction of the fibres. These

---

\* "Cassiterite, 'Sparable Tin,' from Cornwall." By R. H. Solly, M.A. *Mineralogical Magazine*, vol. ix. (1891), p. 199.



specimens were obtained from a lode of copper-ore, and are loosely embedded in a brecciated matrix composed of quartz, chlorite, iron-pyrites, copper pyrites, and brown oxide of iron.\*

In the specimen No. 37, from Fowey Consols, small fibrous concretions of pale brown wood-tin are embedded in a "peachy" vein-stone. No. 38 shows a mass of cassiterite enclosing numerous small globular concretions of wood-tin. Each globule exhibits on the fractured surface a pale brown nucleus, surrounded by an inner ring and an outer zone of dark divergent fibres. In this specimen the cassiterite is associated with lamellar carbonate of lime, or Schiefer spar, an association which is quite exceptional in Cornwall. The specimen probably came from the Garth Mine, near Penzance, and bears Heuland's label, dated 1839, describing it as unique. Pebbles showing the small rings of wood-tin, in varying shades of brown, as seen in some of the pieces in the Tray No. 44, are known as *toads'-eye tin*.

In the interesting specimens Nos. 35 and 36, believed to be from the Sancreed Mine, the wood-tin occurs in brown zones investing quartz. The fracture of No. 35 has disclosed a hexagonal pyramid of quartz, with pitted surface, completely surrounded by dark brown fibrous tinstone, crystallised on the outside of the deposit. The botryoidal form of the free surface of the wood-tin is well seen on No. 36. The matrix seems to be an altered granitic rock, with quartz, pink orthoclase and much cassiterite.

No 40 is an example of the nodular masses of tinstone with fibrous structure, which occurred rather plentifully at one time at Great Wheal Vor Mine, near Helston.† At this mine wood-tin was found as isolated masses, as scattered grains and as small veins, at a depth of about 200 fathoms. The specimen exhibited is not ordinary wood-tin, but fibrous cassiterite of nearly black colour, some of the fibres, however, being brown, slightly translucent and resinous.

It has been pointed out by Mr. J. H. Collins, that ancient ingots of metallic tin, such as those known in Cornwall as "Jews' House Tin," may become coated naturally with an incrustation of tin dioxide, having microscopically a fibro-radiate and concentric structure, very similar to that of wood-tin.‡

By the disintegration of tin-lodes and other stanniferous deposits, the cassiterite may be set free, and after transport by running water be deposited as pebbles, gravel or even fine sand. This is the *stream-tin*, which was formerly found in superficial deposits in many

\* The varieties of wood-tin are fully described by Mr. J. H. Collins, F.G.S., in the second part of his paper "On Cornish Tin-stones and Tin-capels," *Mineralogical Magazine*, vol. iv. (1882) p. 1 (first paper), p. 103 (second paper), and vol. v. (1884), p. 121 (third paper). Reprinted, with additions and corrections, and with separate pagination. Truro: 1888.

† "On the occurrence of wood-tin at the Great Wheal Vor Mines." By G. M. Henty. *Rep. Miners' Assoc. Cornwall and Devon*, 1867, p. 55. "On the occurrence of wood-tin ore in the Wheal Metal Lode at Wheal Vor in Breage." By William Argall. *Journ. R. Inst. Cornwall*, vol. iv. p. 255.

‡ *Min. Mag.*, vol. iv. (1882), p. 111.



parts of Cornwall.\* Several examples of this detrital tin ore are here exhibited (Nos. 41 to 45). No. 41 is a large water-worn fragment from a tin lode, showing the cassiterite attached to vein quartz; No. 42 is a tray of rather large well-rounded pebbles; Nos. 43 and 44 are trays of small fragments of stream-tin including pebbles of agatiform cassiterite and toad's-eye tin; No. 45 is an example of the fine sandy alluvial tin. In the sand the cassiterite is associated with other hard and dense minerals, such as magnetite, ilmenite and native gold, derived from the disintegration of the tin-bearing rocks.

Probably the alluvial deposits of tin-ore in Cornwall attracted attention in prehistoric times, and were worked as a source of the metal before the veins themselves had been attacked by the miner. All the old tin stream-works are now practically exhausted, though certain patches of "tin-ground" continued to be worked until quite a recent period. The tin-streaming carried on at the present time along the Red River, between the parishes of Camborne and Illogan, is confined to washing the tailings, or slimes, allowed to run to waste from the dressing-floors of modern mines. Borings made a few years ago in the lower part of the Red River valley, in quest of true tin-gravels which might have been neglected by the old workers in the district, proved the existence of undisturbed stanniferous alluvium, though no payable patches were detected.†

Gold was found in most of the old stream-works, and the tanners were in the habit of collecting the glittering grains and preserving them in quills. Occasionally, though very rarely, a comparatively large nugget was discovered. One of these exceptional pieces is here exhibited (No. 46). This specimen, from the old stream-works of the Carnon Valley, in the parish of Feock, near Falmouth—a locality famous for its large nuggets—weighs 15·96 grams, or 10 dwts. 6 grains; but the mass is not exclusively gold, the metal being associated with a little vein-quartz.‡

It is known that gold occurs *in situ* in a large number of localities in Cornwall, though it is not generally recognised in tin-lodes. Many years ago Arthur Dean found it in the Great Dowgas Mine, near St. Austell, and in several lead and copper-lodes near Falmouth§; Mr. John Garby obtained it from a cross-course at Wheal Sparnon, near

\* On Cornish stream-tin consult Henwood "On the Detrital Tin-ore of Cornwall," *Journ. R. Inst. Cornwall*, vol. iv., p. 191; and Collins, *ibid.*, vol. xii., p. 64.

† "Alluvial Deposits in the Lower Portion of the Red River Valley, near Camborne." By F. J. Stephens, F.G.S. *Trans. Geol. Soc. Cornwall.*, vol. xii. (1900) p. 324.

‡ Borlase states that the largest piece of Cornish gold known to him was a specimen found in 1756, weighing 15 dwts. 16 grs. Greg and Lettsom cite a Cornish specimen weighing 2 ozs. 3 dwts. For British Gold, see Wall-case No. 14.

§ "Gold in Cornwall," *Rep. Miners' Assoc. Cornwall*, 1865.

Redruth; and the late Mr. S. R. Pattison recorded it from Davidstowe in North Cornwall.\* Many other localities have been cited, and Mr. J. H. Collins remarks that few ores and gozzans are quite free from gold.† In recent years gold has been discovered by Capt. Hambly in the sands of the Menaccan River and in certain gozzans in the Gwennap district; whilst Mr. F. J. Stephens has indicated several localities in which he has detected gold.‡ In Devonshire gold has been found at North Molton, especially in the gozzans of the old Poltimore copper-mine. Probably in many cases the gold has been set free on the decomposition of auriferous pyrites.

An interesting group of specimens, numbered 50 to 67, is intended to illustrate the natural association of cassiterite with other minerals. This relationship, frequently so suggestive in discussing the origin of mineral deposits, is conveniently designated as *paragenesis*—a term introduced more than half a century ago by the Saxon mineralogist Breithaupt.§ The general subject receives copious illustration in the series of veinstones arranged in the Wall-cases 27 to 30, but the small group of specimens immediately under review is limited to the associates of tinstone.

The very common association of cassiterite with *quartz* is seen in many of the specimens, notably in Nos. 50 to 52. In No. 51 the tin-ore is attached to quartz which exhibits in places a beautiful amethystine tint. No. 54 shows the tinstone in company with quartz and *apatite*—the latter a fluo-phosphate of calcium. *Tourmaline*, a very constant attendant on cassiterite, is seen with the tin-ore in No. 55; *fluor-spar* accompanies the cassiterite in No. 56; and *topaz*, in distinct crystals, may be seen alongside the tinstone in Nos. 57 to 59. The cassiterite is associated with *chalybite*, or carbonate of iron, in No. 52; with *mispickel*, or arsenical pyrites, in Nos. 61 and 62; with *copper-pyrites* in Nos. 63 and 64; with copper-pyrites and *zinc-blende* in No. 67; and with *iron-pyrites* and blende in No. 60. An interesting relationship is seen in No. 39, where wood-tin is seated on delicate needle-like crystals of *bismuthite*, or sulphide of bismuth. The study of the various associates of tin-ore will be resumed in subsequent pages (see especially p. 21).

\* "On Auriferous Quartz-rock in North Cornwall." By S. R. Pattison, F.G.S. *Quart. Journ. Geol. Soc.*, vol. x. (1854), p. 247.

† "On the Origin and Development of Ore-Deposits." By J. H. Collins, F.G.S. *Journ. Roy. Inst. Cornwall*, vol. xii. (1894), p. 49.

‡ "The Conglomerates of Cornwall." By Captain Hambly. *Rep. Corn., Polyt. Soc.*, 1897.

§ "Recent Discoveries of Gold in West Cornwall." By Francis J. Stephens F.G.S. *Trans. Roy. Geol. Soc. Cornwall*, vol. xii. (1898) p. 241.

For other references to the gold of Cornwall and Devon see De la Beche's *Report*, p. 613; Greg and Lettsom's *Mineralogy*, p. 237; and Collins' *Mineralogy of Cornwall and Devon*, p. 52.

§ See his work, "Die Paragenesis der Mineralien." Freiberg: 1849.



*Stannite.* (No. 68.)

No. 68 is a typical specimen of the mineral known as *stannite* or *stannine*, in which tin occurs to the extent of between 20 and 30 per cent. in the rare form of a sulphide. The mineral also contains copper and iron, frequently with zinc, and may be regarded as a complex sulphide, or probably rather as a sulpho-stannate, not without some chemical kinship to the mineral known as tetrahedrite (p. 64).\*

Stannite is known also as *tin-pyrites*, the term "pyrites" being a general name applied to many metallic sulphides. By miners the mineral is termed *bell-metal ore*—a term suggested by the colour which it usually presents, and which may be due to an intimate admixture of copper-pyrites. The colour of the purer varieties of stannite seems to be steel-grey or iron-black rather than yellowish.

This mineral was originally discovered at Wheal Rock, near St. Agnes, and has since been recorded from a great number of Cornish localities. At one time it occurred at Carn Brae, near Camborne, in sufficient quantity to be raised as an ore. Granite impregnated with tin-ore, partly in the form of stannite, has been found at Stenna Gwyn, in the parish of St. Stephens.

Crystallised stannite is very rare, and the crystals even when they do occur are often indistinct, so that their type of symmetry has been open to some doubt. It has, however, been shown by Mr. L. J. Spencer that the species belongs to the tetragonal system, and presents forms closely related to those of copper-pyrites.† The Cornish stannite is usually massive, though imperfect crystals, often regarded as cubic, are not unknown.

By the decomposition of stannite the metals which it contains may become converted into oxides and hydroxides, giving rise to a product which has been described under the name of *cupro-cassiterite*. It has been said that in some tin lodes, the metal occurs as an oxide in the shallow workings and as sulphide in the deeper parts. If this really occurs, it must be quite exceptional, the normal condition of tin-ore even in the most profound parts of a lode being that of cassiterite. The tendency of tin to combine with oxygen rather than with sulphur is seen in the alteration which ancient Roman bronzes have suffered on prolonged exposure to thermal waters. Thus, at Bourbonne-les-Bains the bronze medals showed an incrustation of oxide of tin associated with copper sulphides—the two metals of the alloy exposed to like conditions having yielded quite different types of alteration-products.

It is to be regretted that the term stannite is ambiguous, inasmuch as it has also been sometimes applied to a mineral substance which seems to be a mechanical mixture of cassiterite and quartz. (See No. 80, p. 23).

\* "Tabellarische Uebersicht der Mineralien nach ihren krystallographisch-chemischen Beziehungen: Geordnet von P. Groth." 4 Aufl. 1898, p. 39.

† "Crystallised Stannite from Bolivia." By L. J. Spencer, M.A. With Analyses by G. T. Prior, M.A. *Min. Mag.*, vol. xiii. (1901), p. 54.

## DIVISION 2.

## MINERALS OF CORNWALL AND DEVON.

## MINERALS ASSOCIATED WITH CASSITERITE.

(Nos. 69 to 136.)

Numerous examples of the minerals which occur in company with the ores of tin are here grouped together, forming a much larger collection of such minerals than is exhibited in the opposite Division of the Case, and thus giving a wider view of their paragenetic relations. All the specimens here exhibited have been obtained from Cornwall and Devon, but it has not been deemed desirable to limit the collection to specimens actually found in tin-lodes, inasmuch as these may not in all cases fully illustrate the characters of the several species.

*Quartz.* (Nos. 69 to 80.)

This is by far the most common mineral of the tin-veins, forming in some cases the sole matrix of the ore. The vein-quartz is usually white and opaque, rather fatty in lustre, and either compact or crystalline in texture. When granular it is known to Cornish miners as *sugary spar*. Microscopic cavities with liquid inclusions usually abound. It is generally supposed that the vein-stuff must have been deposited from solution. Thermal waters, from deep-seated sources, circulating through the vein fissures, might carry silica in solution and deposit it on the walls of the cavities. In those lodes which are termed *comby*,\* and exhibit a succession of plates of mineral matter, more or less parallel, it is clear that the quartz, which is usually abundant in such lodes, must have been formed in successive deposits on the walls of the veins, inasmuch as the crystals have their apices directed from the walls inwards, and in certain cases the points of the crystals in opposite layers meet and engage each other, like the teeth of two combs. Many *comby* lodes prove, by their structure, that the same fissure must have been re-opened, perhaps several times, and fresh vein-stuff deposited.

The deposition of mineral matter in parallel bands in a vein was termed by the late Professor Posepny *crustification*,† since the successive deposits from a series of crusts, following each other in regular sequence. Beautiful examples of banded or “ribband veinstones” as well as of “*comby* lodes” are exhibited in Wall-cases 29 and 30.

Although the quartz in these veinstones is probably due to hydrothermal action, it is notable that deposits from hot springs rarely

\* For description and figures of *comby* lodes see De la Beche's "Report on the Geology of Cornwall, Devon, and West Somerset" (1839) pp. 339-342.

† "The Genesis of Ore-deposits." By Prof. Franz Posepny. *Trans. American Inst. Mining Engineers*, vol. xxiii. (1894), p. 197. Reprinted, with other papers on the subject, in a separate volume. 1902.



contain quartz. In siliceous sinter the silica usually exists in the hydrated opaline condition; but crystalline quartz has occasionally been found, as in the sinter of Furnas, in the Azores, and in deposits from the warm springs of Mauhourat near Caunterets. Temperature and time are no doubt important factors in the process of crystallisation. As far back as 1845 Schafhäütl obtained quartz in a crystallised condition by heating precipitated silica in a Papin's digester. In Daubrée's classical experiments, crystals of quartz, beautifully formed, though minute, were obtained from the decomposition of glass by means of strongly superheated water.\* It has been shown, however, by M. Kroustchoff that crystallised quartz may be formed at a temperature less elevated than that employed by Daubrée. In Kroustchoff's experiments an aqueous solution of silica was kept for several months in a closed vessel, and exposed periodically to a temperature of 250°C., when crystals of quartz were obtained, of a similar type to Daubrée's, and of a very notable size, some of the prismatic crystals reaching a length of 8 mm.†

W. Bruhns has shown that distinct crystals of quartz may be formed by exposing either amorphous silica or powdered glass to the action of water containing ammonium fluoride at a temperature of 300°C. for a period of ten hours.‡ Here the fluorine seems to act as a mineralising agent, or agent in determining crystallisation. Much of the quartz of the tin-lodes must have been deposited during the early phases of their history, whilst the tin-bearing fluorine compounds were in activity. It has been suggested that some of the quartz may represent the silica set free on the decomposition of hydrofluosilicic acid by means of water.§

During the alteration of the felspathic minerals of granitic rocks into kaolin—an alteration not uncommon in many parts of Cornwall—free silica must be eliminated. Whether the decomposition were effected by hydrofluoric acid from below or by carbonic acid from above, the silica of the alkaline or alkaline-earthly silicate of the felspar would, in either case, be parted from its base. The nascent silica probably assumed in most cases an opaline state, but it is conceivable that under certain conditions it might crystallise. Certain doubly-terminated crystals embedded in china-clay, and apparently destitute of basal attachment, have been tentatively referred to such an origin.

The general characters of quartz will be fully considered when dealing with the sparry minerals of the lodes displayed in Case VI. (p. 90). In the Case under present review there is exhibited only a small series of specimens, yet sufficient to illustrate the crystalline

\* "Études synthétiques." Par A. Daubrée. 1879, p. 164.

† "Nouvelles synthèses du Quartz et de la Tridymite." Par M. K. de Kroustchoff. *Bull. de la Soc. Fran. Min.*, tome x. (1887), p. 31.

‡ "Beiträge zur Mineralsynthese." Neues Jahrbuch. 1880, ii., p. 62.

§ "Traité des Gîtes Minéraux et Metallifères." Par Ed. Fuchs et L. de Launay, Tome ii., 1893, p. 109.

characters and the varied colours of the Cornish quartz. The beautiful tints of the purple amethyst are well seen in Nos. 77 to 79. (For amethyst *see* p. 92.)

In the tray, No. 80, are two specimens of the mineral substance from St. Agnes unfortunately called *stannite*—unfortunately, because the same name has been given to the tin-copper-iron sulphide known as bell metal ore, described on p. 20. The so-called *stannite*, No. 80, seems to be a mechanical mixture of quartz and cassiterite, but has sometimes been described as a silicate of tin. One specimen here exhibited is massive, and the other crystallised. The crystals are six-sided prisms resembling those of quartz, and have been regarded as imperfect pseudomorphs.

Although *stannite* is not truly a silicate of tin it is interesting to note that a silicate containing tin and calcium from Cornwall has been described by Dr. A. Hutchinson, of Cambridge, who has named it *Stokesite* after the late Sir G. G. Stokes. The unique specimen on which the species was founded occurred on axinite, from St. Just, and in its appearance was suggestive of gypsum, but crystallised in the orthorhombic system.\*

#### *Apatite.* (Nos. 81 to 96.)

Although apatite was recognised as a distinct mineral species by the Saxon mineralogist, Werner, at least as far back as 1786, and was soon afterwards found, by the analyses of Proust and of Klaproth, to be a phosphate of lime, yet it was not until 1827 that it became recognised, through the work of Gustav Rose, that the phosphate in this mineral was associated with either a chloride or a fluoride of calcium, or with both. Hence two varieties came to be distinguished—*chlor-apatite* and *fluor-apatite*, of which the latter is the more common. The mineral which accompanies the Cornish tin ore is a fluor-apatite—a fact harmonising with the part which fluorine is believed to have played as a vehicle of tin.

In the south of Norway veins of apatite are very numerous, and Prof. J. H. L. Vogt has instituted an interesting comparison and contrast between these veins and those which carry tin ore.† Both occur in plutonic rocks, but the cassiterite-veins in rocks of acid type, like granite; the apatite-veins in basic rocks, like gabbro. Whilst fluorine was active in the extraction of tin from the acid magma, chlorine appears to have been the chief agent in extracting the minerals of the apatite veins from the basic magma. Hence the Norwegian phosphate is a chlor-apatite, and that of the tin-lodes a fluor-apatite. The apatite-veins carry titanium—a metal having certain chemical relations with tin; and both metals occur in the veins as dioxides—the tin as cassiterite, the titanium as rutile. The

---

\* "On Stokesite, a new mineral containing tin, from Cornwall." By A. Hutchinson, M.A. *Min. Mag.*, vol. xii. (1900), p. 274.

† "Problems in the Geology of Ore-deposits." *Trans. Amer. Inst. Min. Eng.*, vol. xxxi. (1902), p. 125.



pneumatolytic action concerned in the formation of the tin-veins has metamorphosed the neighbouring granite into greisen—an acid felspar being partly converted into topaz, which is a mineral containing fluorine; whilst similar action in the case of the apatite-veins has converted a basic felspar into scapolite, a mineral containing chlorine. Dr. Vogt has estimated that in the tin-lodes there is at least 100 times, and perhaps 1,000 times, as much fluorine as chlorine, while in the apatite veins these proportions are reversed.

Although apatite is a characteristic associate of tin-ore in Cornwall, it is by no means common in well-defined crystals. Its direct association with cassiterite may be seen in No. 81, and again in No. 54. It is a mineral widely distributed through igneous rocks, especially those of basic type, but usually in only microscopic crystals. Apatite is characterised by much stability, and must have crystallised out of the magma at a high temperature. That it belongs to the first phase of consolidation is evident from its common occurrence as inclusions in all other essential minerals, even in magnetite, which itself is generally one of the earliest to separate.

The specimen No. 88 shows the apatite in association with axinite, from the "greenstone" cliffs near Botallack. In No. 83 the apatite occurs in short six-sided prisms, of beautiful blue colour, associated with lithia mica, from St. Michael's Mount. The granite at this famous locality is traversed by miniature tin-lodes, the walls of some of the joints being studded with crystals of quartz, cassiterite, wolfram, apatite, topaz and even beryl, whilst the band of granite adjacent to the vein has been converted into greisen. The late Sir W. W. Smyth said that "there was scarcely anywhere another 100 fathoms square of rock which presented so much of interest to the geologist and mineralogist as this sea-beaten foreshore of St. Michael's Mount."\*

The finest examples of apatite shown in this collection are those from near Bovey Tracey, in Devonshire (Nos. 85 to 92). In some of these specimens the apatite appears in opaque cream-coloured crystals, measuring more than an inch in length, each crystal being simply a six-sided prism terminated by the basal plane. The mineral occurs in granite, and is associated with fine crystals of black tourmaline, as seen notably in Nos. 89 to 91.

The variety of apatite called *Francolite*, of which specimens 93 to 96 are examples, received its name from Wheal Franco, near Tavistock, in Devonshire, where it was originally found.† Prof. N. S. Maskelyne and the late Dr. Flight showed that in some kinds of francolite the calcium phosphate of the fluor-apatite is partially replaced by calcium carbonate.‡ No. 96 is a specimen of this

\* "Remarks on the Geology of St. Michael's Mount, by Warington W. Smyth, F.R.S., at the Annual Excursion of the Mining Association and Institute of Cornwall." *Proceedings of the Assoc.*, vol. i., part 3, 1887.

† "On Francolite, a supposed New Mineral." By T. H. Henry, Esq., F.R.S. *Phil. Mag.*, vol. xxxvi. (1850), p. 134.

‡ *Journ. Chem. Soc.*, [2] vol. ix. (1871). p. 3.

nature.\* All the examples of francolite shown here were obtained by the late Mr. Talling from Fowey Consols, near Lostwithiel. It will be seen that in some of these specimens the mineral occurs in the form of small white hexagonal plates, with curved faces. Francolite from deep workings at Levant Mine, St. Just, has been described by Mr. R. H. Solly.†

*Topaz. (Nos. 97 to 99.)*

Topaz occurs in certain granitic rocks, perhaps in some cases as an original constituent, and is not uncommon in the rocks of the West of England. Dr. Teall has described its occurrence in a variety of granite from Meldon, near Okehampton, in Devonshire.‡ In most cases topaz is a secondary mineral, resulting usually from the alteration of felspar. It is a characteristic constituent of the greisen, or altered granite which occurs in the neighbourhood of certain tin-lobes. In the process of kaolinisation, part of the silica and all the alkaline base are removed from orthoclase; and a somewhat similar change, with addition of fluorine, might produce an aluminium fluo-silicate like topaz. In this mineral fluorine exists to the extent of 17 or 18 per cent. Prof. Penfield has shown that the fluorine may be partially replaced by hydroxyl.§ Such a medium as hydrofluoric acid would probably be competent, under certain conditions, to effect the conversion of felspar into topaz. In the well-known synthetical experiments by Daubrée, a substance analogous to topaz was formed by the action of fluoride of silicon on alumina at a white heat.|| Topaz has been artificially prepared by MM. Friedel and Sarasin by the action of hydrofluo-silicic acid on silica and alumina, with water, at a temperature of 500°C.

Whilst topaz is in many cases a mineral of secondary origin, it tends itself to suffer alteration, and to pass into kaolin and micaceous minerals like sericite.

The specimens of topaz here exhibited represent its occurrence at Cligga Head, (Nos. 97 and 98) and at St. Michael's Mount (No. 99). Other specimens from the latter locality will be found in the opposite division of the case (Nos. 57 to 59).

The occurrence at Cligga Head, between St. Agnes and Perranporth on the north coast of Cornwall, has been studied by Mr. J. B. Scrivenor, whose paper on this subject has already been referred to.¶ The topaz occurs on the face of the joints in the altered granite. The

\* "Note on Francolite." By F. H. Butler, M.A., A.R.S.M. *Min. Mag.*, vol. vii. (1887), p. 164.

† *Min. Mag.*, vol. vii. (1887), p. 57.

‡ "British Petrography." By J. J. Harris Teall, M.A. 1888, p. 316.

§ "On the Chemical Composition and related physical properties of Topaz." By S. L. Penfield and J. C. Minor, jr. *Am. Journ. Sc.*, vol. xlvii. (1894), p. 387.

|| "Études Synthétiques de Géologie expérimentale." Par A. Daubrée, 1879, p. 57.

¶ *Quart. Journ. Geol. Soc.*, vol. lix. (1903), p. 142.



occurrence at St. Michael's Mount is similar. The crystals are colourless or of pale blue tint, and some of the specimens, where not distinctly crystallised, might be mistaken on a cursory inspection for quartz. Topaz, however, crystallises in the orthorhombic system, and the crystals usually present, as seen here, a prismatic habit, the prisms being striated longitudinally and presenting a perfect basal cleavage.

In connection with the West of England topaz it may be mentioned that the mineral occurs also in the granite of Lundy Island.\*

*Fluorite.* (Nos. 100 to 104.)

Whilst fluorite, or fluor-spar, is the most widely distributed of all minerals which contain fluorine, it is not so common in the tin mines of Cornwall as might have been anticipated. Many tin-lodes, especially in the West of Cornwall, seem destitute of fluor-spar, whilst many veins rich in fluor-spar carry no tin. Most of the crystallised specimens, such as the fine series exhibited in Case V., have been obtained from the copper-veins and lead-veins of Cornwall and Devon. The full description of the mineral will, therefore, be deferred until that Case comes under review (*see* p. 85).

The specimen No. 100 shows the fluor-spar in direct association with cassiterite. The spar is known to Cornish miners as *Cann*.

In the "china stone," or altered granitic rock worked in the neighbourhood of St. Austell, the walls of the joints are sometimes lined with deep purple fluorite. The mineral seems to be connected with the tin-carrying fluoric compounds, which were probably responsible for much of the alteration. Dr. Boase recorded fluor-spar from the Hensbarrow granite. Fluorite rarely occurs as a rock constituent, but it was found by the late Mr. R. N. Worth in a granitic rock on the north-western flank of Trowlesworthy Tor, on the skirts of Dartmoor, whence he called the rock *Trowlesworthite*.† This is an aggregate of bright red orthoclase, deep violet fluorite, black acicular tourmaline, and a very little quartz. Prof. Bonney, who examined the rock microscopically, believes that trowlesworthite has been formed from the normal granite of the district by the replacement of quartz by fluor-spar.‡

*Fluellite.* (Nos. 105 to 109.)

Several specimens of this extremely rare mineral are here exhibited. It was first detected eighty years ago by Lévy,§ and examined by Wollaston, who found that it contained fluorine and aluminium.

\* "On the Occurrence of Topazes in Lundy Island." Letter by Mr. S. G. Perceval in *Geol. Mag.*, vol. vii. (1870), p. 192.

† *Trans. Roy. Geolog. Soc., Cornwall*, vol. x. (1887), p. 177.

‡ *Ibid.*, p. 180; also, *Min. Mag.*, vol. vi. (1884), p. 48.

§ "On a new Mineral Substance." *Ann. Phil.* [n.s.] vol. viii. (1824), p. 241.

An analysis made by Dr. Brandl, at Prof. Groth's request, has confirmed this determination, and proved that the mineral is a hydrated fluoride of aluminium.\*

Stenna Gwynn, near St. Austell, is the only known locality. Here it occurs in very small crystals, of pyramidal habit, belonging to the orthorhombic system. These are seated on a quartzose matrix, and associated with cassiterite, fluorite, uranite, muscovite, and wavellite. Fluellite therefore takes its place in company with the other fluorine-bearing associates of tin-stone.

### *Lithia Mica.* (No. 110.)

Lithium-bearing micas are rather characteristic of granites which carry tin-stone and tourmaline. The typical mica, called—from its occurrence in scaly aggregates—*Lepidolite*, usually presents a lilac or rose-colour, with a rather pearly lustre on the cleavage planes. The presence of a little manganese seems to be responsible for these tints. The amount of lithium may reach 5 per cent. and of fluorine 8 per cent. Boron is also usually present, as in several other minerals friendly to tin-stone.

A lithium-iron mica, occurring characteristically in the stanniferous rocks of Zinnwald, in Bohemia, is known as *zinnwaldite*, and some of the Cornish micas in silvery hexagonal plates may be referable to this type. The Zinnwald mica has been found to contain rubidium, caesium and thallium. The presence of tin has also been recorded in certain lithia-micas, and in some cases it appears to be present in the form of microscopic inclusions of cassiterite.

### *Gilbertite.* (Nos. 111, 112.)

A yellowish or greenish micaceous mineral, observed originally at Stenna Gwynn and since found in several china-stone districts in Cornwall, as at St. Austell and Breage, has been distinguished by the name of *Gilbertite*—a name given by Dr. Thomas Thomson, in compliment to Davies Gilbert, the “Cornish philosopher,” who was, at one time President of the Royal Society (*b.* 1767, *d.* 1839.) The specimens here exhibited show the mineral in stellate aggregates of pearly scales. Being rather unctuous to the touch, it has sometimes been mistaken for talc.

Gilbertite appears to be an alteration-product of felspar, and pseudomorphs of gilbertite in the form of orthoclase are known. It is probable, as Mr. F. H. Butler remarked, that in some cases the gilbertite represents one of the stages in the gradual kaolinisation of orthoclase.†

The specimen No. 112 shows an association of gilbertite with crystals of apatite.

\* “Beiträge zur Kenntniss der natürlichen Fluorverbindungen.” Von P. Groth. *Zeitsch. f. Krystallographie*, vol. vii. (1883), p. 482.

† *Min. Mag.*, vol. vii., p. 79.



*Tourmaline.* (Nos. 113 to 120.)

Tourmaline is perhaps, with the exception of quartz, the most constant associate of tin-ore. Doubt has, however, been sometimes expressed as to such a relationship.\* It is true that crystals of tourmaline are not commonly to be seen in the lodes, but the mineral is nevertheless present in microscopic crystals distributed through the rocks of most tin-districts. Rocks which are stanniferous, whether granite or killas, are almost invariably tourmaliniferous. The *tin capels*, which are bands of altered rock, adjacent to the veins, and generally found near the junction of the granite and the killas, are always rich in tourmaline. The mineral is chiefly developed near the margin of intrusive masses of granite, and in the zone of contact-metamorphism. It appears to have been formed by the action of vapours containing boron and fluorine, attacking the felspathic and micaceous constituents of the rocks.

Tourmaline is a boro-silicate of complex and variable constitution, containing aluminium, iron, magnesium and the alkali-metals, with fluorine and hydroxyl. The proportion of boric oxide generally ranges between 8 and 10 per cent., but may rise higher. Free boric acid is not uncommon in the exhalations from fumaroles, notably in those of Tuscany. Mr. Donald MacAlister has suggested that the metaborate of sodium, formed by the action of boric acid on the felspars, might have been an active chemical agent in the transport of tin.†

According to a striking calculation by Mr. J. H. Collins, the tourmaline-bearing rocks of the West of England contain something like 2,480,000 tons of fluorine for each yard in depth.‡ This result is based, however, on the liberal estimate that the tourmaline contains an average of 2 per cent. of fluorine, and that the mineral constitutes 10 per cent. of the rock.

Most of the tourmaline of Cornwall and Devon, though coloured in thin sections, appears black when viewed in mass by reflected light. This black, ferriferous tourmaline is known as *schorl*.§ It frequently occurs in acicular crystals or in fibrous masses (No. 119). In No. 118 the slender crystals are grouped in stellate aggregates. Tourmaline belongs to the hexagonal system, and commonly assumes the form of three-sided prisms, striated longitudinally, giving on transverse section characteristic triangular figures, and carrying

\* "La Tourmaline, loin d'accompagner régulièrement l'oxyde d'étain, semble exercer sur lui une action répulsive." "Note sur la Constitution des gîtes stannifères de la Villeder (Morbihan)." Par M. Lodin. *Bull. Géolog. Soc. Fr.* [3 série], t. xii. (1884), p. 645. M. Lodin holds that the views of Daubrée are not applicable to the tin-deposits described in this memoir.

† "Tin and Tourmaline." By Donald A. MacAlister, Esq. *Quart. Journ. Geol. Soc.*, vol. lix. (1903), p. 53.

‡ "On the Origin and Development of Ore-deposits in the West of England." By J. H. Collins, Cap. III, *Journ. Roy. Inst., Cornwall*, vol. xi. (1893), p. 371.

§ The word *schorl* is said to be derived from the old German miners, and *tourmaline* from the Sinhalese.

rhombohedral faces at their extremities. The mineral is remarkable for its hemimorphism,\* for its pyroelectric properties and for its optical characters. A fine series of specimens, mostly from foreign localities, and including many gem stones, will be found in the Horse-shoe Case, Section R.

Magnificent crystals of black tourmaline were obtained many years ago from a small quarry of red granite not far from Bovey Tracey in Devonshire.† Examples of these bold crystals are here exhibited as Nos. 113 to 116. They were embedded in a matrix of ochreous clay in a cavity of the granite, and were associated, as will be seen in these specimens, with crystals of quartz and apatite. The crystals of tourmaline are mostly short stout prisms, with rhombohedral terminations; and it is notable that whilst some of the faces are smooth and brilliant others are rough and dull. In No. 115, and in some of the other specimens, the apatite appears to have been formed after the tourmaline.

The beautiful rock described by Professor Bonney under the name of *Luxullianite* is rich in tourmaline.‡ This rock consists of pink orthoclase, in large twin crystals, embedded in a dark matrix of schorl and quartz. Boulders of the rock are found at Luxullian, near Lostwithiel, and the largest known mass was used for the sarcophagus of the Duke of Wellington in St. Paul's. Specimens may be seen in the Rock Collection, and some beautiful polished examples will be found among the ornamental stones in the Hall.

In many of the Cornish granites, tourmaline displaces, to a greater or less extent, the micaceous and felspathic constituents, having probably been formed at their expense, and when the replacement is complete the resulting aggregate of quartz and tourmaline is known as *schorl-rock*. Such a rock is associated, in several localities, with the occurrence of tin-stone. Spheroidal masses of schorl-rock may occur as enclosures in the normal granite.

Whilst tourmaline may be formed by the alteration of micaceous minerals, there are circumstances under which it seems to be itself changed to mica. Topaz may likewise be an alteration-product of tourmaline. As a rule, however, the mineral is characterised by much stability, and when set free by the disintegration of a rock it may survive in the form of rolled fragments and be ground down as sand. Mr. A. Dick found that about one-tenth per cent. of the Lower Bagshot sands of Hampstead Heath, north of London, consisted of grains and crystals of tourmaline.§

\* Crystals are said to be *hemimorphic* when their opposite extremities are dissimilarly developed, or, technically, when they possess axes of symmetry which are polar. Hemimorphism is often correlated with pyro-electric properties.

† "On the Mineral Localities of Devonshire." By Townshend M. Hall. *Trans. Devon. Assoc.*, vol. ii. (1868), p. 332.

‡ *Min. Mag.*, vol. i. (1877), p. 215.

§ *Nature*, vol. xxxvi. (1887), p. 91.



*Axinite.* (Nos. 121 to 124.)

Axinite is a boro-silicate of complex composition, rather like tourmaline, and originally regarded as a kind of schorl. It differs, however, from tourmaline in occurring usually in basic eruptive rocks rather than in those of acid type, though not altogether unknown in the latter.

If the Cornish specimens are not comparable for beauty with the fine crystals of axinite from Dauphiny they yet illustrate sufficiently the general characters of the species. They occur as clove-brown brilliant crystals, belonging to the anorthic system, with the sharp axe-like edges that suggested to Haüy the specific name.

The Dauphiny crystals, of which specimens may be seen in the Horse-shoe Case (Section Θ) occur in a zone of amphibolite and chlorite schists.\* Those of Cornwall are typically developed in the greenstones and hornblende schists displayed in the cliffs north of Botallack Head, at Wheal Cock and at Trewellard, north of St. Just. Some of the specimens here shown are from Terrace Hill, Lost-withiel. Pseudomorphs of chlorite after axinite are recorded from Dartmoor and from St. Just. The Cornish axinite has been analysed by Mr. J. E. Whitfield.†

*Wolframite.* (Nos. 125 to 130.)

*Wolfram*, or *Wolframite*, is a mineral which in Cornwall, as in so many other parts of the world, follows close in the train of the tin-ore. In some of the Cornish tin-lodes it has been found "inconveniently plentiful," inasmuch as it is not easy to separate it from the tin stuff by mechanical dressing, the specific gravity of the wolfram standing very near to that of cassiterite (about 7). Magnetic separation has recently been used.

Wolfram occurs usually in opaque brownish-black cleavable masses, with a lustre so brilliant as to be almost adamantine. Occasionally it occurs in crystals, as seen in these specimens, which show the crystallised wolfram associated with quartz. Formerly the crystals were regarded as orthorhombic, but they are now claimed by the monoclinic system. Wolfram is an iron and manganese tungstate, containing when pure about 60 per cent. of the metal tungsten or wolframium. It is used in the preparation of tungsten-steel, a small proportion of tungsten being found to increase the hardness and tenacity of the metal.

Wolfram is raised to a limited extent from several mines in Cornwall—Carn Brea, Tin Croft, East Pool and Agar United Mines. The quantity raised in the year 1901 was, according to official statistics, 21 tons, valued at £408.

---

\* "Minéralogie de la France et de ses Colonies." By A. Lacroix, vol. i., p. 277. Paris, 1893.

† *Amer. Journ. Sc.* [3], xxxiv. (1887), p. 286.

By exposure to influences which remove the iron and manganese, wolfram becomes encrusted with a yellowish earthy coating of *Wolframine* or *wolfram ochre*, known also as *tungstite*. This mineral, consisting of tungsten trioxide, is seen on specimen No. 132, from East Pool Mine.

*Scheelite.* (No. 131.)

*Scheelite* is a calcium tungstate not common in Cornwall, but occasionally occurring as an alteration-product of wolfram. The two isolated crystals of this species shown here are little bipyramids, which, notwithstanding their resemblance to regular octahedra, belong to the tetragonal system. The other specimen in the tray, No. 131, is an example of scheelite, in a chloritic matrix, from Wheal Friendship, near Tavistock in Devonshire.

The species will be again referred to in connection with the much finer specimens which occur in Cumberland (p. 153).

*Mispickel.* (Nos. 133 to 136.)

The solfataric emanations which appear, from so many lines of evidence, to have arisen from an acid magma and to have been active in the formation of the deposits of tin ore in the West of England, must have been laden not only with fluorine and boron but likewise with sulphur and arsenic. The latter elements combined with iron constitute the mineral called *Mispickel*—one of the most constant associates of tinstone.\*

In Case V there is a series of metallic sulphides, headed by the commonest species known as iron-pyrites. The name *pyrites* has come to be used as the designation of a group of related minerals, all sulphides with a metallic aspect, and in this group mispickel is included. It is, therefore, known, from its composition, as *arsenical pyrites*, or, since pyrites is called by Cornish miners "mundic," the mispickel is known also as *arsenical mundic*. The term "mispickel" itself comes from an old German name for this, or a similar mineral.

Mispickel is an arseno-sulphide of iron, generally showing, when freshly fractured, a white colour and metallic lustre. It crystallises in the orthorhombic system, frequently in twin crystals. Further description of the species will be found in connection with the section dealing with pyrites (p. 62).

---

\* A *solfatara* ought literally to exhale vapours containing sulphur (Italian *solfo*). Vapour-vents emitting, at a higher temperature, chlorine compounds are often termed *fumaroles*; but the nomenclature is lax. Pneumatolytic emanations were evolved from the deep-seated magma, under pressure. Probably the fluorine-bearing vapours concerned in the production of tin-ore came from the hottest subterranean fumaroles; and it has been supposed that the sulphur-carrying vapours represented a rather cooler phase of emission.

On the genesis of ore-deposits see Prof. J. F. Kemp's paper on "The Rôle of the Igneous Rocks in the Formation of Veins." *Trans. Am. Inst. Min. Eng.*, vol. xxxi. (1902), p. 169.



Although mispickel occurs in both tin-lodes and copper-lodes in the West of England, it seems to be more common in the former. It is generally found in veins running through killas near to granite, but is not common in the granite itself. In some Cornish mines it seems to have great vertical persistence, increasing in quantity downwards, and thus leading to the inference that it may be a vein mineral of very early formation.

Arsenical pyrites is still raised in Cornwall and Devon, though to a less extent than formerly. During the year 1901 the quantity of the mineral raised in Cornwall was 2,334 tons, and in Devonshire 244 tons. This arsenic ore is roasted for the production of arsenious anhydride, or "white arsenic." According to the official statistics, the amount of arsenic, partly as "soot" and partly as "white arsenic," refined at the mines, and obtained principally from the arsenical pyrites of the tin and copper mines, was 1,258 tons in Cornwall and 2,103 tons in Devonshire.

---

## CASE II.

## DIVISION 1.

## MINERALS OF CORNWALL AND DEVON.

## COPPER SULPHIDES AND SULPHO-FERRITES.

(Nos. 137 to 204.)

The ores of copper, next to those of tin, are the most important metal-bearing minerals yielded by the mines of the Damnonian Peninsula. In the early days of Cornish tin mining the copper-ores, which were not infrequently found in association with those of tin, were altogether neglected. Carew, writing in the beginning of the seventeenth century, says: "Copper is found in sundry places, but with what gain to the searchers I have not been curious to enquire nor they hasty to reveal."\* After Carew's time a hundred years had to pass before the copper-ores of Cornwall came to be systematically worked.

At one time it was believed that the ores of copper in Cornwall were restricted to the western part of the peninsula—a belief which found expression in the saying "No copper east of Truro Bridge." That idea was dispelled, however, long ago; and mines of great value have been worked far beyond the old restricted limit. Nevertheless, the most important workings for copper at the present time are in the extreme west. During the year 1902 Levant Mine in St. Just turned out not less than 3,056 tons of dressed copper ore.

No sharp line of separation can be drawn between the deposits of copper-ore and those of tin. The lodes run in the same general direction, and in many cases the same vein may carry both tin and copper. The specimen, No. 137, shows the association of copper pyrites with crystals of cassiterite. Some mines have been worked at one time for tin, at another for copper; and it has not infrequently happened that copper-lodes have carried more or less tinstone in their upper or gozzany part. Certain mines which were worked originally for tin ore have yielded copper ore at lower levels, and then at yet greater depths the copper has given way to tin. It has been said that in many cases the copper minerals seem to have been of later introduction than the tin ore, but it is doubtful whether such a conclusion admits of wide application. Mr. J. B. Hill believes that the copper and tin are of "approximately identical age,"†

---

\* Survey of Cornwall. Ed. 1811., p. 21.

† *Trans. R. Geol. Soc. Corn.*, vol. xii., part vii. (1902), p. 593.



whilst Mr. D. MacAlister thinks, with reference to the Camborne district, that "probably the copper arrived either before the tin, or at the same time."\*

It has been observed that in mixed deposits the copper generally occurs where the vein traverses killas, whilst in granite it may be displaced by tin. Some of the lodes, for instance, near Tavistock, in Devonshire, produced copper while in killas, but only tin after passing into the Dartmoor granite. At the junction of the two rocks, rich bunches of copper-ore have sometimes been found, and they have also occurred in the killas far from any visible granite.

The primary condition of the copper in the veins of Cornwall and Devon, as in many other copper-mining localities, appears to be that of copper-pyrites—a sulphide of copper and iron, containing theoretically about 34 per cent. of metallic copper. In the higher part of the vein the pyrites may be associated with, or even replaced by, the richer copper sulphides known as purple ore and copper glance. The sulphides thus become progressively richer in copper as they approach the surface—an enrichment probably due, at least in part, to the removal of the iron sulphide in the copper-pyrites, by means of solution. The succession of minerals may be represented in descending sequence as follows, though the order may be subject to much local irregularity.

Copper glance ( <i>Chalcocite</i> ),	with 80 per cent. of copper.
Purple copper ore ( <i>Erubescite</i> ),	„ 55 „ „
Copper pyrites ( <i>Chalcopyrite</i> ),	„ 34 „ „

It is worth noting that at the famous copper mines of Monte Catini, in Tuscany, there are nodules of ore which show a succession of minerals arranged in zones following the same order. The central part of the nodule is copper pyrites, which passes into purple ore, and this gives way towards the exterior to copper glance, whilst even native copper may appear on the surface.

It seems fair, however, to point out that successive changes of precisely the inverse order may be traced on metallic copper after prolonged exposure to the action of thermal waters. Roman bronze coins, for example, found in the spring of Bourbon-l'Archambault, in Central France, have exhibited a central core of unaltered metal, followed from within outwards by successive zones of copper glance, purple ore and copper pyrites.† Mr. S. F. Emmons has observed that as the tendency to establish a condition of chemical equilibrium in a reaction may be modified by varying conditions of temperature, pressure and strength of the reacting solutions, it is conceivable that the reaction may proceed in the reverse direction under altered conditions.

The concentration of copper in the region of rich sulphides may be due, not only to the removal of the iron from copper-iron sulphides, but also to the direct deposition of copper sulphide from circulating

\* *Trans. R. Geol. Soc., Corn.*, vol. xii., part viii. (1903), p. 773.

† *Comptes Rendus*, vol. lxxx. (1875), p. 1297.

solutions. This secondary enrichment has been ably discussed by such geologists as Prof. S. F. Emmons\* and Mr. W. H. Weed.† Near the surface copper-pyrites would be prone to oxidation, and the copper sulphate so formed and carried downwards in solution might suffer reduction not only by organic matter but by such metallic sulphides as iron pyrites, and thus a precipitate of fresh sulphide of copper might be produced.

In the copper-veins of Cornwall, as pointed out by the late Mr. Arthur Collins, three zones may be roughly recognised, though in many cases they are by no means sharply separated :

1. *Zone of oxidation or weathering*, which will be described under the head of gozzans (p. 41).
2. *Zone of sulphide enrichment*, in which the secondary sulphuretted ores have been produced.
3. *Zone of primary sulphide*, which may be copper-pyrites, or poor cupriferous iron pyrites.

In the West of England the rich ore-belts have in many cases been passed through, and a region of impoverished ore has been reached. "Copper mining," wrote Sir C. Le Neve Foster,‡ "is an industry which is rapidly decreasing in importance in Britain." During the year 1902, the mines of Cornwall produced 4,547 tons of dressed copper ore, valued at £12,374 ; whilst in Devonshire only 350 tons were raised, having a value of £637.

#### *Chalcopyrite. (Nos. 137 to 164.)*

The most-common ore of copper in the mines of the West of England, as in so many other localities, is a combination of copper, iron and sulphur, constituting the mineral usually known as *Copper-pyrites*. By mineralogists it is now generally designated by Beudant's name *Chalcopyrite*. A suggestion made long ago by Brooke and Miller that the mineral should be termed *Towanite*, after Wheal Towan, a mine near St. Agnes, which yielded fine crystals of this species, is a suggestion which was never widely adopted. By miners the mineral is generally known as *yellow ore*. When the tinstone of a lode is replaced by a deposit of this ore, the miner would say that "The yellows cut out the tin."

Chalcopyrite crystallises in the tetragonal system, usually in hemihedral forms.§ The crystals present a sphenoidal habit, with the faces in many cases curved and striated. Twin crystals are

---

\* "The Secondary Enrichment of Ore-deposits." *Trans. Am. Inst. Mining Eng.*, vol. xxx. (1901), p. 177.

† "The Enrichment of Gold and Silver Veins." By Walter Harvey Weed, *Ibid.*, p. 424.

‡ Home Office Report (part III., Output). 1903, p. 200.

§ A *Hemihedral* form is one in which only half the number of faces required by the full symmetry of its system are developed. It may be regarded as formed from a holohedral form by the symmetrical suppression of half the faces.



common. The angles of the sphenoid are so close to those of the regular tetrahedron that the species was referred to the cubic system until the measurements of William Phillips, aided by Lévy, in 1822, showed that "pyritous copper" was not cubic.\* At the same time the mineral was carefully analysed by his brother Richard Phillips. Crystals of Cornish chalcopyrite have been studied by Mr. L. Fletcher† and by Professor J. W. Lewis‡, not to mention continental crystallographers. For good crystals, see Nos. 138 to 153.

Although crystals of chalcopyrite are common enough in collections, the mineral usually occurs in the Cornish lodes in compact or amorphous masses. In some cases it presents mammillary and botryoidal forms, which are known as *Blister ore*. Such forms are seen in Nos. 161 to 164.

Chalcopyrite presents a rich golden yellow colour, but tends to tarnish on exposure. The tarnish is sometimes brilliantly iridescent, when the mineral becomes known as *peacock ore* (Nos. 154, 155). Iron-pyrites may be associated with copper-pyrites as an intimate mechanical mixture, and in this way the latter loses its characteristic colour, becoming much paler. The two kinds of pyrites are distinguished not only by colour but by hardness, the copper-pyrites yielding readily to a knife whilst the iron-pyrites is too hard to be scratched by a steel point.

In chalcopyrite the three constituent elements are present in nearly equal proportions. The formula for chalcopyrite,  $\text{CuFeS}_2$ , yields: copper 34·6 per cent., iron 30·5, and sulphur 34·9; but analyses often show an excess of iron, probably due to admixture with iron-pyrites.

It is usual to regard chalcopyrite as a double sulphide of copper and iron, and since it yields, by alteration, copper glance ( $\text{Cu}_2\text{S}$ ) it is supposed to contain a molecule of cuprous sulphide, whence its formula is often written  $\text{Cu}_2\text{SFe}_2\text{S}_3$ . But chalcopyrite may also be viewed as a sulpho-ferrite; that is to say, it may be regarded as a derivative from a sulpho-acid,  $\text{FeS}_2\text{H}$ , by replacement of the hydrogen by univalent copper.§

The recent formation of copper-pyrites has been illustrated by the action of thermal waters on objects containing copper. Thus, at Bourbonne-les-Bains and at Bourbon-l'Archambault, in Central France, copper-pyrites has been formed on old Roman bronze coins. The sulphur in such cases is supplied by the sulphates which the

\* "On the Crystalline Form of Yellow Copper Ore." By William Phillips. *Annals Phil.* [n.s.], vol. iii., p. 296.

† "Crystallographic Notes." By L. Fletcher, M.A. *Proc. Crystallogical Soc.*, part ii. (1882), p. 114. Also Groth's *Zeitsch. Kryst.*, Bd. vii. (1883), p. 321.

‡ "On some remarkable Composite Crystals of Copper Pyrites from Cornwall." By Prof. W. J. Lewis, M.A., and A. L. Hall, B.A. *Min. Mag.*, vol. xii. (1890), p. 324.

§ "Tabellarische Uebersicht der Mineralien nach ihren krystallographisch-chemischen Beziehungen. Geordnet von P. Groth." 4 Auf., 1898, p. 29.

waters contain, and which are reduced to sulphides by the decomposition of organic matter. Crystals of copper-pyrites have also been formed inside the copper tubes used for conveying thermal waters near Pest.\*

The paragenetic relations of copper-pyrites are well illustrated by the specimens in the Case under review. No. 137 shows chalcopyrite and cassiterite side by side. The common association with quartz is seen in many of the specimens, notably in Nos. 139, 146, 149, 150, and 153. With calcite the Cornish chalcopyrite occurs much less frequently, but examples are shown from the Caradon mines in No. 147. Chalybite, or carbonate of iron, is a frequent companion of copper-pyrites, as seen in Nos. 142 and 145. In No. 158 chalcopyrite is associated with fluor-spar; in Nos. 140, 156, and 157, with fluor-spar and quartz; and in No. 160 with francolite, a variety of apatite. Copper-pyrites also occurs, rather exceptionally, with boro-silicates like tourmaline and axinite, as at the Belstone mines, in Devonshire, whence was obtained the specimen No. 159, which exhibits the interesting association of chalcopyrite with garnet and axinite.†

*Chalcocite.* (Nos. 165 to 192.)

Next to chalcopyrite, *copper glance* is the most abundant ore of copper. This is a native cuprous sulphide, known to mineralogists under a variety of names, such as *Chalcocite*, *Redruthite*, and *vitreous copper ore*. It occurs usually in the upper part of the lodes, above the copper-pyrites, though in some cases the two sulphides are intermingled. Probably much of the chalcocite may be regarded as a secondary sulphide, produced by the alteration of copper-pyrites.

A large series of Cornish specimens of chalcocite, exceptional for their beauty, is exhibited in this Case. The mineral crystallises in the orthorhombic system, and some typical examples illustrating its prismatic habit are here shown (Nos. 170, 171). The name *redruthite*, sometimes applied to this species, recalls the fact that many of the finest crystals have been brought to light from mines in the neighbourhood of Redruth. In many cases the crystals assume a hexagonal habit which led some of the early mineralogists to refer the species to the hexagonal system. Many fine examples of these pseudo-hexagonal crystals, principally from St. Ives, will be recognised here, notably Nos. 172 to 175. Twin crystals and triplets are not infrequent, giving rise to star-shaped structures. It is easy to understand from the shape of some of the crystals how the miners have been led to call them "nail-headed copper ore."

Chalcocite is usually of a dark lead-grey colour, but many of the crystals when fresh present a brilliant steel-grey appearance. On exposure, the mineral is apt to suffer alteration, and acquire a dull

\* "Lehrbuch der Mineralogie." Von Dr. Gustav Tschermak, 4 Auf., 1894, p. 354.

† "Notes on Minerals from Cornwall and Devon." By R. H. Solly, M.A., F.G.S. *Min. Mag.*, vol. vi. (1886), p. 202.





black surface. In other cases the surface becomes encrusted with the blue copper sulphide, called *covellite*. It may also become coated, under the influence of meteoric agencies, with copper carbonates and other epigenic minerals, as is illustrated by No. 189—a beautiful specimen of copper glance in which malachite is creeping over the crystals.

Chalcocite is remarkably soft, sectile and fusible—so soft as to be readily cut with a knife, like a piece of horn, and so fusible as to melt in the flame of a candle. When massive as an ore it is sometimes called “black copper ore” and “grey copper;” but these names are ambiguous, inasmuch as the former is applied also to the oxide called melanconite, and the latter to fahlerz or tetrahedrite. Some forms of chalcocite are pulverulent and sooty.

Copper glance usually, though not invariably, occurs near the outcrop of an ore-deposit, and gives way in depth to the yellow and purple ores. Pseudomorphs of chalcocite after chalcopyrite are known, and von Jeremeeff described their occurrence in quartz veins near Georgeiff, in the Altai, where every stage from copper-pyrites to copper glance may be traced.\* It should be noted, however, that the converse change likewise occurs, pseudomorphs being known in which copper-pyrites has replaced copper glance.

Chalcocite may be produced by the reaction of sulphate of copper on copper-pyrites or even on iron-pyrites. It is known as a pseudomorph replacing organic structures, and some specimens of wood mineralised with chalcocite are shown in the Case of specimens illustrating Fossilisation.

Roman bronze coins, and other objects containing copper, after exposure to the prolonged action of certain thermal waters, have yielded crystallised chalcocite. Some of Daubreé’s well known examples from Bourbonne-les-Bains exhibited crystals of cuprous sulphide which strongly reminded the mineralogist of the natural crystals of Redruth, on a small scale.

#### *Covellite.* (Nos. 191, 192.)

Whilst *cuprous sulphide* constitutes the mineral described above as chalcocite or copper glance, the *cupric sulphide* (CuS) also occurs native and forms a mineral known as *Covellite*. This name was given to it as a compliment to Covelli, an Italian mineralogist who showed that cupric sulphide occurs among the erupted products of Vesuvius. It is easy to understand how such a substance may be formed, by the reaction of sulphuretted hydrogen on cupric chloride, which is a volatile body found among certain volcanic exhalations.

Whilst the Vesuvian covellite is crystallised in forms belonging to the hexagonal system, the covellite in copper-veins is usually found as a blue incrustation on other copper sulphides, from which it has evidently been derived. It is not uncommon as an alteration-product on chalcocite, chalcopyrite and erubescite; witness such

---

\* *Zeit. f. Kryst.*, vol. xxxi. (1899), p. 508.

specimens as are shown here. By Breithaupt it was called *Kupfer-indig*, or indigo copper, since it bears some resemblance to indigo not only in colour but in general appearance.

It has been shown experimentally by A. Knop that covellite may be formed by the action of hydrochloric acid on copper glance or on purple copper-ore—in the former case rapidly, in the latter slowly. Some of the copper is removed as chloride, and the cuprous sulphide ( $\text{Cu}_2\text{S}$ ) by this loss of copper passes into the condition of cupric sulphide ( $\text{CuS}$ ).\*

Hochstetter recorded the occurrence of covellite as a thick dark blue incrustation on an axe-head of bronze and on metallic copper from a prehistoric site near Hallstatt, in Austria.†

*Erubescite.* (Nos. 193 to 204.)

Cornwall is remarkable, among mineral localities, for its fine crystals of chalcocite already described, and not less for its crystals of *Erubescite*. These crystals have been obtained chiefly from the mines of Carn Brea, Tincroft, and Cook's Kitchen—three typical localities near Redruth.

Erubescite crystallises in the cubic system, and many of the specimens here exhibited show characteristic forms, such as interpenetrating cubes. It will be noted that some of the faces are slightly curved, and in many cases the crystals instead of being distinctly developed are confusedly aggregated, whilst in some cases the groups of crystals take a marked linear extension.

When freshly fractured the mineral presents a bronzy or coppery appearance, but it rapidly suffers tarnish, especially in moist air, and frequently becomes iridescent. The name *erubescite*, given by Dana, is suggestive of the reddish tint which the mineral sometimes assumes. In most cases, however, the superficial colour tends towards purple, probably due to the formation of covellite, whence the common name *purple copper-ore*. The tarnished surface is often vivid in lustre and varied in tint—so varied that the German miners call it *Buntkupfererz*, or *variegated copper-ore*. In consequence of the bluish red appearance of the mineral, the Cornish miner commonly terms it *horse flesh ore*.

Erubescite was regarded by the early mineralogists as a form of copper-pyrites, and it was not definitely separated from this species until its crystalline characters and chemical composition came to be understood. William Phillips first showed that the mineral was cubic, and in his honour Beudant named it *Phillipsite*, a name which is unfortunately ambiguous, since it is applied also to a certain zeolitic mineral. Among the many designations of this copper-ore is included the name *Bornite*, applied to it in compliment to Ignatius von Born, a mineralogist who had charge of the mineral collection in Vienna in the latter part of the eighteenth century. This name,

\* *Neues Jahrbuch*, 1861, p. 533.

† *Sitzungsber. Ak. Wiss. Wien*. Bd. lxxix., Abth. I. (1879), p. 122.



given as far back as 1845, seems in truth to have priority over Dana's erubescite, but the word bornite is apt to be confused by miners with bournonite.

Purple copper-ore is generally regarded as a double sulphide of copper and iron, chemically akin to yellow copper-ore. Pure specimens conform to the formula  $\text{Cu}_3\text{FeS}_3$ , but the massive ore exhibits considerable variation in composition, probably due to mechanical mixture with copper glance or with copper-pyrites. According to Rammelsberg, erubescite may be viewed as a combination, in varying proportions, of the three sulphides— $\text{Cu}_2\text{S}$  and  $\text{CuS}$  and  $\text{FeS}$ . Groth's view regards it as a sulpho-ferrite of copper, derived from the normal sulpho-acid  $\text{Fe}(\text{SH})_3$  by replacement of its hydrogen by copper :  $\text{Fe}(\text{SCu})_3$ .

The specimen No. 204 is notable for showing the erubescite in the form of lenticular chalcocite, and in association with calcite. The pseudomorphs after chalcocite suggest one way in which it may have been formed. It is probable, however, that in many cases it has resulted from the alteration of copper-pyrites, and perhaps even of iron-pyrites, by the action of waters containing copper sulphate.

Illustrations of the neogenic formation of erubescite are furnished by the Roman coins and other bronze objects, which were thrown as votive offerings into certain thermal springs, as at the famous waters of Bourbonne-les-Bains, described long ago by Daubrée. After exposure to the action of these waters for some sixteen centuries, the metal objects have become partially converted into various copper-bearing sulphides, such as chalcocite, chalcopyrite and erubescite. The subject will be referred to again, in connection with the mineral called tetrahedrite, which has also been formed, and is perhaps the most interesting of all these epigenic formations.

---

## DIVISION 2.

### MINERALS OF CORNWALL AND DEVON.

#### COPPER-BEARING MINERALS OF THE GOZZANS.

(Nos. 205 to 272.)

In a mineral-vein which carries pyrites in any form, it is usual to find that the upper part of the deposit contains much brown oxide of iron, or ferric hydrate. This rusty ore has resulted from the alteration of the pyritic constituent of the lode under the influence of oxidising agencies, and is therefore practically confined to the zone of weathering. It usually marks the "back" or outcrop of the lode. A tin-lode fairly free from pyrites is not likely to carry a ferruginous capping of great extent, but most tin-lodes contain more or less iron pyrites or mispickel, which may yield on decomposition hydrated oxide of iron. In copper-lodes, however, this ferruginous mass is

usually present in conspicuous amount, the iron of the copper-pyrites yielding the brown hydrate; and its characteristics are held by experienced miners to bear some relation to the nature of the underlying ore-body. The oxide of iron is generally associated with much of the quartzose veinstone, which is apt to present a cavernous or honey-combed aspect, due to removal of the pyritic minerals.

This cellular mass of ferruginous matter is known in Cornwall as *gozzan*, in France as the *chapeau de fer*, and in Germany as the *eiserner Hut*. The connection between gozzan above and ore below has been regarded as so well established that it has given rise among German miners to an old adage, which has appeared in several English variants:

“A Lode that wears no iron hat,  
Is never likely to be fat.”

Since the formation of the gozzan is generally due to the alteration of pyrites, or in some cases to the alteration of carbonate of iron, it may be assumed that it will be found only in the shallow part of a mine, in the upper zone above the water level of the country, or in what the late Prof. Posepny termed the *vadose region*.<sup>\*</sup> Below the plane of saturation, whither the influences that effect oxidation fail to penetrate, the metallic sulphides may retain their original character with but little alteration. It may happen, however, that these agencies, operating along deep fissures, make themselves felt at considerable depths. Thus in Cornwall the gozzan has extended to as great a depth as 100 fathoms below the adit level at Fowey Consols: in Ting Tang Mine the gozzan went down to 150 fathoms; whilst at Dolcoath oxidised products have been found as deep as the 197 fathom level.<sup>†</sup>

In the weathering of iron-pyrites the sulphide is oxidised to the condition of ferrous sulphate, with formation of free sulphuric acid. This sulphate, perhaps after passing to the condition of ferric sulphate, is ultimately converted into ferric hydrate, or, as it is sometimes called, hydrate of iron. The reactions in the oxidation and hydration of pyrites have been studied by Mr. W. H. Weed and by Mr. R. A. F. Penrose.<sup>‡</sup>

It is probable that the alteration of pyrites to limonite is often effected through the intermediate formation of ferrous carbonate, a rather unstable compound easily decomposed in the presence of air and water, with production of ferric hydrate. Dr. J. W. Evans has called attention to the action of carbonates in promoting the limonitisation of pyrites. His experiments showed that metallic sulphides exposed to water free from carbonates are usually converted into sulphates, but that the presence of carbonates determined

---

<sup>\*</sup> On the circulation of subterranean water, see Prof. van Hise's papers: "Principles controlling the Deposition of Ores." *Journ. Geol.*, vol. viii. (1900), p. 730. *Trans. Am. Inst. Min. Eng.*, vol. xxx. (1901), p. 27.

<sup>†</sup> On Cornish Gozzan, often spelt Gossan, see W. Argall in *Rep. Min. Assoc.*, 1872, p. 37. Also J. H. Collins in *Journ. R. Inst. Corn.*, vol. ix., p. 471.

<sup>‡</sup> *Journal of Geology*, vol. ii. (1894), p. 288.



the formation of oxides, hydrates and carbonates. In the case of iron-pyrites, the first product of alteration in the presence of carbonates is usually the hydrated oxide.\*

The specimen No. 205 is a sample of gozzan from a copper-lode at Devon Great Consols. A large series of examples will be found among the vein-stones in Wall-case 35. They are not showy specimens, but are of much significance to the miner, since the character of the gozzan usually bears some relation to that of the ore-body, though sometimes it happens that a rich gozzan may cap a lean lode.

To the mineralogist the gozzany part of a vein is often of supreme interest, for many of the finely crystallised specimens of oxides, carbonates, phosphates, arsenates and other oxysalts, have had their birthplace in the region of the gozzan. An extensive series of such specimens, including many of great beauty, is exhibited in the Case under description and in some of the succeeding Cases.

#### *Cuprite.* (Nos. 206 to 226.)

Two oxides of copper occur in a native condition—the *red* or *cuprous* oxide ( $\text{Cu}_2\text{O}$ ) and the *black* or *cupric* oxide ( $\text{CuO}$ ), forming the minerals known respectively as cuprite and melaconite. In the mines of Cornwall and Devon these copper oxides have usually been derived from the alteration of copper sulphides.

*Cuprite*, or *red copper ore*, not unfrequently occurs in sharply defined crystals, of the cubic system, rich in colour and brilliant in lustre. The crystals, as shown here, are usually octahedra, or less commonly cubes and rhombic dodecahedra. Some of the specimens (such as Nos. 210, 214, 215) present a colour, lustre and translucency which justify the name of *ruby copper ore*, sometimes applied to this species. As the mineral is apt to become dull and opaque by prolonged exposure to light the finest specimens are not exhibited in this Case. Wheal Phoenix, near Liskeard, yielded at one time crystals of cuprite, which in beauty and brilliancy rivalled gem stones; and many of these specimens are preserved in japanned tin cases in the Ludlam cabinets, where they may be seen by students, on application to the curator.

A remarkable variety of cuprite is furnished by the capillary forms known as *Chalcotrichite* or *plush copper* (Nos. 225, 226). These delicate filaments, of carmine colour and silky lustre, are acicular crystals, the system of which was formerly a matter of dispute; but they are now known to be cubes greatly elongated, usually in the direction of a diagonal.

In many of the specimens, such as Nos. 206 and 207, the association of cuprite with limonite reveals its origin from copper-pyrites, the sulphides of the two metals, copper and iron, being here represented by the oxides. An intimate mixture of cuprite and limonite is sometimes found as an earthy substance, brick red or reddish brown in colour, and is known to miners as *tile ore*.

---

\* "The Alteration of Pyrite by Underground Water." By John W. Evans, LL.B., D.Sc. *Min. Mag.*, vol. xii. (1900), p. 371.

At the beginning of the nineteenth century, great discoveries of red copper-ore were made in Cornwall, where it had previously been a very rare mineral. Mr. W. Phillips described and figured the fine crystals from Wheal Gorland, near St. Day in Gwennap.\* Here there were three lodes, but most of the cuprite was yielded by the gozzany part of the Muttrell Lode, "one to which no other lode hitherto discovered in the county of Cornwall bears any analogy." The gozzan extended to a considerable depth, and yielded a great deposit of cuprite, associated with native copper, copper glance, black oxide and arsenate of copper, mispickel, quartz and fluorspar. It is believed that many of the specimens of cuprite here exhibited were obtained from this deposit.

Cuprite is not unfrequently found in a crystalline condition on ancient objects of copper or bronze, which have lain long in damp ground. Bronze celts sometimes show this alteration. The surface of the object is coated with green carbonate of copper, beneath which is a crust of red oxide, enveloping a nucleus of the original alloy. In certain cases bronze coins show a similar change. Mr. L. Fletcher has described an interesting case of the occurrence of piles of Roman coins at Chester, which had been buried for fifteen centuries, where the cavities between the piles were lined with crystals of red oxide and with blue and green carbonates of copper, associated with yellow carbonate of lead.† Professor Lacroix has described in like manner the alteration of old Roman coins from Algeria, where the metal has yielded cuprite, malachite and cerussite.‡ In the thermal waters of Bourbonne-les-Bains, and at some other localities, crystals of cuprite have been found on some of the bronze objects which have been exposed for centuries to the action of the waters.

The artificial production of cuprite was effected by Mitscherlich, by the slow reduction of a solution of copper sulphate through the agency of organic matter. It is believed that a similar de-oxidation may be effected by means of ferrous compounds, and a simple explanation is thus afforded of the possible formation, in certain cases, of the natural oxide.

#### *Melaconite.* (Nos. 227, 228.)

Cupric oxide in its native condition is known as *Melaconite*, and occurs usually as a dull earthy pulverulent substance, coating other copper-ores from which it may have been derived. In No. 228 it encrusts chalcosite. Crystals are extremely rare, and the crystallised specimen No. 227 is interesting as having been obtained from

---

\* "A Description of the Red Oxyd of Copper, the Production of Cornwall and of the Varieties in the form of its Crystal, with Observations on the Lodes which principally produced it; and on the Crystallization of the arseniated Iron." By William Phillips. *Trans. Geolog. Soc.*, vol. i. (1811), p. 23.

† "On Crystals of Cuprite and Cerussite resulting from the slow alteration of Buried Coins." By L. Fletcher, M.A. *Min. Mag.*, vol. vii. (1887), p. 187.

‡ *Bull. Soc. Min. Fr.*, tome vi. (1883), p. 175.



Mr. Talling, and being the counterpart of the material studied by Prof. Maskelyne, who described the crystals forty years ago.\* They belong to the monoclinic system. These crystals were analysed by Professor Church, who was the first to call attention to their occurrence.†

The substance termed *black copper ore*, which occurs in the gozzan of many copper lodes, is a more or less impure form of melaconite. This black ore was known to old Cornish miners as *poder*—a word which De la Beche suggests may be a corruption of the word “powder,” applied to the ore in consequence of its pulverulent character.‡ The value of this substance, so unattractive to the eye, was for a long time ill understood, and according to Pryce a quantity representing several thousand pounds in value was washed into the sea from Old Pool Mine.

Crystalline scales of cupric oxide occur on Vesuvian lavas, and are known mineralogically as *Tenorite*. There they are no doubt formed by sublimation, whilst in copper-lodes the mineral results from the alteration of copper-ores, such as chalcosite, with which it is often associated.

#### *Native Copper.* (Nos. 229 to 244.)

*Native copper*, known to miners as *virgin copper* or *malleable copper*, occurs to a greater or less extent in almost all the copper mines of Cornwall. It is usually found in the upper or gozzany part of the lode, where it has evidently been formed as a secondary product by the reduction of certain cupriferous compounds. Rarely, if ever, in well defined crystals, it often assumes dendritic and arborescent forms, spreading out in picturesque branches, or expanding in thin laminae, or shooting out in delicate filaments like moss. Some of the branches are aggregates of small distorted crystals. The characteristic association of native copper with cuprite is illustrated by Nos. 221–224.

Copper is reduced with such facility from solutions of its salts, especially the sulphate, that the formation of native copper presents no difficulty. In old mine workings, metallic copper may be readily precipitated from cupreous waters by means of metallic iron; and in this way such objects as iron chains, bolts and nails will readily throw down *cement copper*. Decomposing organic matter is also an agent of reduction, and hence decaying wood frequently determines the local precipitation of the metal. Mr. W. H. Baker has described the occurrence of crystals of native copper on mine timber at the Kawan Mine, in New Zealand, found on re-opening the workings after they had been closed for twenty years. Some instructive examples of metallic copper formed around wood and iron objects, in old mines, will be found in Wall-case 35.

\* “On Crystals of Melaconite, and on Tenorite.” By Prof. Maskelyne, M.A. *Brit. Assoc. Rep.*, 1865, p. 33.

† *Chem. News*, Mar. 17, 1865. p. 122.

‡ *Rep. Geol. Cornwall*, p. 591.

Native copper may also be reduced from cupreous solutions by natural electrolytic action, or by the influence of deoxidising media, like metallic sulphides, or even magnetite. Probably ferrous sulphate has been in many cases the reducing agent. It has been shown that the conditions under which ferrous salts may be oxidised with deposition of metallic copper are precisely those which obtain in the circulation of underground waters.\*

Pseudomorphs of native copper having the form of octahedral crystals of cuprite are well known. The copper is in a spongy condition, through loss of matter, and has probably been formed by the action of weak sulphuric acid, which would give rise to cupric sulphate and free copper.† A similar reaction may have been responsible for the origin of large masses of native copper.

On the contrary, native copper may give rise to cuprite and other oxidised compounds, by exposure to meteoric influences. Metallic copper, in its natural condition is, however, very slowly affected by oxidising agencies.

The specimen No. 248 shows native copper embedded in the serpentine of the Lizard district, in south-western Cornwall.

In the Hall of the Museum are some very large masses of native copper from a mine at the Ghostcroft, Mullion, where it occurred near the junction of the serpentine with hornblende schist. These were exhibited, with some still larger specimens, in the Great Exhibition of 1851.‡

In the well-known copper-deposits of Monte Catini, near Florence, the ore occurs in connection with masses of serpentine and gabbro. The commonest mineral is copper-pyrites, but this in some parts passes superficially into erubescite, chalcocite and native copper. The Tuscan serpentine has been regarded as an altered cupriferous peridotite. According to B. Lotti§ the ores may have resulted from the differentiation of a strongly basic eruptive magma, rich in magnesium—a view supported by Vogt.||

Copper is a metal much more widely distributed in nature than tin. Its ores occur not only in igneous rocks of acid type, like those which carry tin ore, but also—and perhaps more frequently—in basic eruptive rocks.

#### *Malachite and Chessylite. (Nos. 245 to 252.)*

Any body of copper ore, on exposure to meteoric activities, is apt to become more or less altered to the condition of carbonate. The

\* "The Deposition of Copper by solutions of Ferrous Salts." By H. C. Biddle. *Journ. Geol.* (Chicago), vol. ix. (1901), p. 430.

†  $\text{Cu}_2\text{O} + \text{H}_2\text{SO}_4 = \text{Cu} + \text{CuSO}_4 + \text{H}_2\text{O}$ . With respect to precipitation in the zone of weathering, see W. H. Weed: "The Enrichment of Gold and Silver Veins." *Trans. Amer. Inst. Min. Eng.*, vol. xxx. (1901), p. 424.

‡ On the Lizard copper, see F. J. Stephens. *Trans. R. Geol. Soc. Corn.*, vol. xi. (1895), p. 680.

§ "Sulla genesi dei giacimenti metalliferi nelle rocce eruttive basiche." *Boll. d. R. Com. Geolog. d'Italia*, vol. xxiv. (1893), p. 343.

|| "Beiträge zur genetischen Classificationen der durch magmatische Differentiationsprocesse und den durch Pneumatolyse entstandenen Erzvorkommen."—*Zeit. f. prakt. Geol.*, Oct. 1894, p. 381.



brilliant colours of the carbonates of copper render them conspicuous on the back of the lode. Specimens are here shown of the green carbonate or *Malachite* (Nos. 246 to 248) and of the blue carbonate or *Chessylite*, known also from its colour, as *Azurite* (Nos. 250-252). These related minerals are often associated, as in No. 250. The Cornish specimens usually occur as encrustations, sometimes fibrous but rarely crystallised. The delicate green fibrous malachite in No. 248 comes from South Caradon, near Liskeard. The crystals on No. 251 show chessylite in a pseudomorphous form, replacing crystals of the arsenate called clinoclase.

The recent formation of carbonate of copper is illustrated by No. 245, which is a sample of a material raised at one time as an ore at Wheal Leisure, near Perranzabuloe. This consists of grains of sand, with pebbles and recent shells, cemented by copper-ore, chiefly green carbonate, which is known to have been formed in the course of fifteen years by the action of rain-water percolating through the waste heaps of an old mine. This specimen was presented, with others, by the late Sir Warington Smyth, F.R.S.

Of a somewhat similar character is the specimen, No. 246, recently obtained by Mr. J. B. Hill, of the Geological Survey, in which green carbonate of copper of recent formation is associated with shelly sand from Carbis Bay.

Malachite and chessylite are usually described as hydrated carbonates, but as the water is not expelled until the minerals are exposed to a high temperature it may be assumed that the water is constitutional, the hydroxyl acting as a base; hence the minerals are really basic carbonates.

#### *Chrysocolla.* (Nos. 253, 254.)

Copper may appear as a silicate wherever copper ores are exposed to the action of siliceous solutions. The copper silicate known as *Chrysocolla* presents a bluish green colour, with an opaline lustre, and is usually found in botryoidal or encrusting masses. The specimens here shown are well-defined crystals of cuprite, converted superficially into chrysocolla, with retention of perfect form. *Chrysocolla* seems in all cases to be an amorphous product of the alteration of other copper ores, and the form presented by these specimens is of course pseudomorphous.

#### *Chalcanthite.* (Nos. 255, 256.)

Although sulphate of copper must be a very common product of the oxidation of copper sulphides, its ready solubility in water renders it unfit to survive, as a mineral, amid the damp surroundings of a mine. It is, therefore, only under rather exceptional conditions that the solid salt is found in nature. As a mineral, the cupric sulphate is known as *Chalcanthite* or *cyanosite*. The specimens here exhibited show the beautiful blue colour which has led to the common name *blue vitriol*. In one of the specimens the salt exhibits

a fibrous structure, whilst another shows the mineral in small sharply-defined anorthic crystals, seated on killas. The burrows, or heaps of old mine-refuse occasionally contain chalcantbite.

A solution of sulphate of copper draining through a mineral vein furnishes a ready means for migration of the copper. It is probable that such cupreous solutions, descending to lower levels, may effect the secondary enrichment of many copper lodes by furnishing material from which copper sulphides may be precipitated, as pointed out by Mr. S. F. Emmons and Mr. W. H. Weed in the papers already cited (p. 35).

*Langite, Woodwardite, etc. (Nos. 257 to 266.)*

The beautiful mineral *Langite* is a basic cupric sulphate, described in 1864 by Prof. N. S. Maskelyne, who detected it on specimens sent to the British Museum by the late Mr. Talling.\* It occurs on killas and on a quartzose veinstone, in the form of minute blue crystals belonging to the orthorhombic system: it is found also as an incrustation and as a cementing medium in a breccia of killas. Mr. Collins gives its localities as Copper Hill Mine and Wheal Bassett, Redruth; and East Pool, Dolcoath and other mines near Camborne.†

*Langite* was so named by Prof. Maskelyne in compliment to Prof. Viktor von Lang, of Vienna, who was at one time an officer in the mineralogical department of the British Museum. *Lyellite* is Maskelyne's name for a somewhat similar mineral, which Pisani called *Devilleine* (No. 262).‡

It was pointed out by Maskelyne and Flight that solutions of sulphate of lime or magnesia reacting on malachite might give rise to a basic cupric sulphate like *langite*.§

Closely associated with *langite* is another mineral which Prof. Maskelyne described at the same time under the name of *Waringtonite*—a name given in honour of the late Sir Warington W. Smyth, who was for many years lecturer on mineralogy and mining at the Royal School of Mines, and in that capacity had charge of the mineral collections in this Museum (b. 1817, d. 1890).

Under the name of *Woodwardite* Professor Church described, in 1866, a Cornish mineral which he found to be a hydrated cupric-aluminium sulphate.|| The specimen shown here presents the mineral in the form of a thin crust having a peculiarly rippled

\* "A new British Mineral."—*Phil. Mag.*, vol. xxvii. (1864), p. 316.

† "A Handbook to the Mineralogy of Cornwall and Devon," 1871, p. 61.

‡ *Comptes Rendus*, vol. lix. (1864), p. 813.

§ *Journ. Chem. Soc.*, [2] vol. ix. (1871), p. 2. *Chemical News*, vol. xxii., (1870) p. 259.

|| "Chemical Researches on New and Rare Cornish Minerals. iv. A New Hydrated Cupric-aluminum Sulphate." *Journ. Chem. Soc.*, [2] vol. iv. (1866), p. 130.



surface and a beautiful turquoise blue colour. The name was given in memory of Dr. S. P. Woodward, of the British Museum, the author of the well-known "Manual of the Mollusca" (b. 1821, d. 1865). The mineral has close relations to langite.

No. 265 is a specimen of a stalagmitic mineral of recent formation, found by Sir C. Le Neve Foster at St. Agnes, and described as *Enysite* by Mr. J. H. Collins, who found it to be a basic sulphate of copper and aluminium.\*

*Connellite.* (Nos. 267, 268.)

The extremely rare mineral *Connellite* is a hydrous sulphato-chloride of copper, which was first examined chemically by Prof. Connell,† after whom it was named by Dana. It occurs in delicate diverging fibres, of a fine Prussian blue colour, belonging to the hexagonal system. The crystallographic characters of the species have been described by Prof. Maskelyne, and the chemical by Prof. Penfield.‡

No. 268 is the specimen referred to by Greg and Lettsom, when they say: "In Mr. Turner's collection there is a specimen stated in the catalogue to be from Carharrack in St. Day."§ In Lévy's catalogue of 1837 it is described as *cuivre velouté*, without any reference to its composition.|| The mineral is associated in this specimen with cuprite and a little mispickel, on a matrix of quartz.

In the catalogue of the Rashleigh collection—a collection recently acquired by the Royal Institute of Cornwall, through the generosity of Mr. Enys and others, and now exhibited in the museum at Truro—there is a figure of connellite, described as "copper ore of an azure blue colour composed of needle crystals."¶

About twenty years ago the mineral was found in the Camborne district and in Marke Valley, and its occurrence was described by Mr. W. Semmons.\*\* It occurred in copper veins traversing killas, and was associated with cuprite, malachite, brochantite, etc. The crystals were described by Prof. Miers†† and by Dr. C. O. Trechmann.‡‡

The somewhat similar mineral, termed by Prof. Penfield *Spangolite*, has been detected on Cornish specimens by Prof. Miers.§§

\* *Min. Mag.*, vol. i. (1877), p. 14.

† "On Sulphato-chloride of Copper—a new mineral."—*Brit. Assoc. Rep.*, 1847, part ii., p. 49.

‡ "On Connellite from Cornwall, England." *Amer. Journ. Sc.*, [3] vol. xl. (1890), p. 82.

§ *Manual of the Mineralogy of Great Britain*, etc., p. 347.

|| Vol. iii., p. 100, No. 4.

¶ "Specimens of British Minerals selected from the Cabinet of Philip Rashleigh." Part ii., 1802, p. 13, Pl. xii., fig. 1.

\*\* "Notes on a recent Discovery of Connellite." By W. Semmons. *Min. Mag.*, vol. vi. (1886), p. 160.

†† *Ibid.*, p. 167.

‡‡ *Ibid.*, p. 171.

§§ "Spangolite." By H. A. Miers, M.A. *Min. Mag.* vol. x. (1894), p. 273.

*Atacamite, etc. (Nos. 269 to 272.)*

In certain parts of the world the chlorides of copper have played at times an important part in the production of copper, but in Cornwall they occur only as great rarities. Atacamite, the oxychloride, which is the best known member of the group, finds no place among the British minerals described in Greg and Lettsom's standard work. Indeed, it was not recognised as a British species until recorded by Prof. Church in 1865.

The specimens show the mineral in minute crystals (No. 270), as an incrustation and in the form of tubular stalactites (No. 269). In some places atacamite may have been formed by the action of salt-water on oxides of copper, as pointed out by Mr. Cloud with reference to the famous occurrence at Wallaroo in South Australia.\* The specimens here shown are from Botallack Mine, close to the sea; but chlorides may also be formed inland, since rain water usually contains more or less salt.

The infiltration of sea-water into a part of Botallack Mine was no doubt responsible for the formation of the cupric oxychloride which Prof. Church described as *Botallackite*, of which a specimen is seen in No. 271.†

*Tallingite* (No. 272) is another mineral closely related to atacamite described by Prof. Church.‡ The name recalls the services of an observant collector, the late Mr. R. Talling, who brought to light several new minerals from the West of England, and from whom a large number of the specimens here exhibited were originally obtained.

\* "Note on Atacamite." By T. C. Cloud, A.R.S.M. *Chem. News*, vol. xxxiv. (1876), p. 254.

† "Notes on a Cornish Mineral of the Atacamite Group." *Journ. Chem. Soc.* [2], vol. iii. (1865), p. 212.

‡ "On some Hydrated Cupric Oxychlorides from Cornwall." *Journ. Chem. Soc.* [2], vol. iii. (1865), p. 77.



## CASE III.

## DIVISION 1.

## MINERALS OF CORNWALL AND DEVON.

## ARSENATES AND PHOSPHATES FROM THE COPPER GOZZANS.

(Nos. 273 to 340.)

The series of secondary minerals found in the gozzans of the copper lodes is continued in this Case by an extensive group of the arsenates and phosphates of copper. Many of the old mines of Cornwall were famous for these minerals, and the beautiful specimens here exhibited fully justify their reputation. Other examples as fine, or even finer, will be found in that part of the Ludlam collection which is exhibited in the Hall.

In the Cornish veinstones, arsenic seems to be more common than phosphorus, and it will consequently be observed that in this Case the arsenates form a grander show than the phosphates. The arsenic seems to have been originally brought up, in association with iron and sulphur, as arsenical pyrites. The species called *mispickel* has already been noticed (p. 31) and will again be referred to in connection with pyrites (p. 62). Mispickel contains theoretically nearly half its weight of arsenic; but even in ordinary pyrites, arsenic may be present in small proportion. The alteration which arsenical pyrites suffers in the oxidation-zone of a vein has no doubt furnished material for the formation of various arsenates. The mine-waters in Cornwall are known to be frequently arsenical.

The original source of the phosphorus in the phosphatic minerals of the veinstone is perhaps not quite so obvious. It has, however, been probably derived, directly or indirectly, from apatite. This mineral, as already remarked (p. 24), is widely distributed in eruptive rocks, both acid and basic, but especially the latter. At a very early stage in the consolidation of the magma, the phosphorus separated as calcium phosphate, and the minerals which subsequently crystallised had to mould themselves around the pre-existing crystals of apatite. Hence the apatite usually appears as inclusions enveloped in the other rock constituents.

It is true that in some cases, the apatite appears to offer much resistance to agents of alteration, and its crystals may remain fresh even when the surrounding matter has suffered more or less decomposition. But, on the other hand, apatite is known to be readily attacked by acids, even by water containing carbonic acid, and it has undoubtedly furnished phosphatic matter to the circulating waters, which would help to form metallic phosphates in the vein. Sulphuric

acid, from decomposing pyrites in a vein, will readily attack apatite. Again, all surface water contains more or less calcium phosphate, probably derived, for the most part, from organic sources; and, hence, surface drainage may carry phosphates into the shallow parts of a lode, and so give rise to reactions resulting in the formation of secondary phosphates as minerals of the gozzan.

The chemical composition of the arsenates and phosphates has been the subject of prolonged researches by Prof. A. H. Church\*; and the subject has been taken up in recent years by Mr. G. J. Hartley.†

*Olivenite, Libethenite, etc.* (Nos. 273 to 302.)

It will be seen from the rather large series of specimens of *olivenite* (Nos. 273 to 296) that the olive green colour, which led Werner to name the species, is subject to much variation. Nos. 273 and 274 show brilliant crystals, belonging to the orthorhombic system, seated on brown iron-ore, so as to show their relation to the gozzan, and presenting a very dark green colour, inclining to black. *Wood copper*, or *wood arsenate*, is the name applied to the fibrous varieties, which often appear in delicate filaments, with a silky lustre, frequently of pale colour passing into ash grey or even white, and sometimes disposed in masses which present a velvet-like surface. Examples of the fibrous *olivenite* are exhibited in Nos. 290 to 296.

Most of the *olivenite* here shown, as well as some of the other copper arsenates in this Case, came from Wheal Unity, in the parish of Gwinear. Mr. W. Semmons has remarked that "Wheal Unity was a perfect storehouse of copper minerals, no less than fourteen combinations of that metal being found there."‡

*Olivenite* is generally described as a hydrated arsenate, but the water is probably represented by hydroxyl, and the mineral may, therefore, be regarded as a basic arsenate of copper. Its formula,  $\text{Cu}_2(\text{OH})\text{AsO}_4$  suggests its derivation from ortho-arsenic acid.§ The series of arsenates and phosphates are isomorphous||, and part of the arsenic in *olivenite* is consequently replaced in many cases by phosphorus, without disturbance of crystalline character. When the replacement is complete, the resulting compound has the formula  $\text{Cu}_2(\text{OH})\text{PO}_4$ . This constitutes the mineral known as *Libethenite*—a mineral which owes its name to a locality in Hungary. In Cornwall this phosphate is even more rare than *olivenite*. Specimens are shown as Nos. 297 to 302. In some of these examples the *libethenite* is crystallised on gozzany ironstone, and in others on malachite—associations which in both cases recall the formation of the phosphate as a secondary mineral.

\* *Journ. Chem. Soc.*, various volumes from 1865.

† "On the Constitution of the Mineral Arsenates and Phosphates." *Min. Mag.*, vol. xii. (1900), pp. 120, 152, 223.

‡ *Min. Mag.*, vol. vi., p. 160.

§ See Groth, *op. cit.*, p. 89.

|| *Isomorphous* substances are those which possess analogy of chemical composition with close resemblance, or even identity of crystalline form.



The rare phosphate of copper called *Lunnite*, or *pseudo-malachite*, is represented by Nos. 301, 302. Specimens from Botallack were analysed by Prof. Church.\*

*Clinoclase and Cornwallite.* (Nos. 303 to 311).

*Clinoclase* is a basic copper arsenate corresponding among the arsenates to pseudo-malachite among the phosphates. It occurs in dark greenish-blue crystals, referable to the monoclinic system, the name expressing the fact that the basal cleavage is inclined to the faces of the oblique prism. No. 304 shows the mineral in the form of a spherical mass, with curved cleavage-planes; whilst Nos. 305 to 307 illustrate its characteristic occurrence in dark blue fibres aggregated in diverging and stellate groups.

The very rare mineral, *Cornwallite* is a hydrated basic arsenate of copper, occurring in small botryoidal masses. Its composition has been determined by Prof. Church.† and the specimen here exhibited as No. 309 is interesting as being a portion of the specimen which he analysed. Other examples of cornwallite are shewn in Nos. 310, 311.

The Cornish arsenates of copper were studied in the beginning of the last century by the Comte de Bournon, who was led to remark that "Nature has established very remarkable differences between the arseniates of copper."‡ The justice of this remark will be admitted by the visitor who, sweeping his eye over the minerals in this Case, contrasts the superficial characters of such species as olivenite, clinoclase, liroconite and chalcophyllite.

*Liroconite.* (Nos. 312 to 321.)

From all other copper arsenates the species termed *liroconite* is usually distinguished by its beautiful sky-blue colour. The mineral occurs in sharply defined crystals, belonging to the monoclinic system, and the old name *octahedral arseniate of copper* was intended to indicate their general shape. This species differs from the arsenates previously noticed, inasmuch as it contains aluminium as an essential constituent: it may be regarded in fact as a hydrated basic arsenate of copper and aluminium. It seems to have been found only in Wheals Unity, Gorland and Muttrell, in Gwennap; and, as some of the specimens here show, it was found with other oxidised products in the gozzany part of the veinstone. Some exceptional specimens of this species are included in the Rashleigh collection now in the museum of the Royal Institution of Cornwall at Truro.

\* *Journ. Chem. Soc.* [2], vol. iii. (1865), p. 2.

† *Journ. Chem. Soc.*, [2] vol. vi. (1868), p. 276.

‡ "Description of the Arseniates of Copper and of Iron, from the county of Cornwall." By the Count de Bournon. *Phil. Trans.*, vol. xci. (1801), p. 169.

*Chalcophyllite.* (Nos. 322 to 328.)

The rare and beautiful mineral called *Chalcophyllite*, known also as *Tamarite* from its occurrence at Wheal Tamar, is represented by a series of excellent specimens. It crystallises in the hexagonal system, and the crystals usually assume a tabular habit, as well seen in most of the examples here exhibited. The six-sided plates present perfect basal cleavage, whence the name *copper mica*, sometimes applied to this species. The shape and the fine emerald green colour give the mineral in some cases a certain resemblance to "uranium mica," or torbernite (p. 82).

Chalcophyllite has generally been regarded as a hydrated basic arsenate of copper and aluminium, but the analysis of a Cornish specimen, carefully separated from foreign matter, by Mr. E. G. J. Hartley, has revealed the presence of a sulphate.\*

Some of the specimens here exhibited show the chalcophyllite associated with chalcopyrite, and others with decomposing mispickel, thus betraying the origin of the mineral. In No. 328 the substance seems partially altered to chrysocolla.

*Bayldonite, etc.* (Nos. 329–331.)

Under the name *Bayldonite*, in honour of Dr. John Bayldon, at one time Professor in the Royal Agricultural College at Cirencester, Prof. Church described, some forty years ago, a new species, which occurs as a concretionary mineral of green colour, seen in Nos. 329 and 330, where it coats a gozzany quartzose veinstone. This species is a hydrated basic arsenate of copper and lead.†

No. 331 is a specimen of *Chenevixite*, which is a hydrated basic arsenate of copper and iron, occurring as a dull greenish amorphous substance on a quartzose matrix.

*Andrewsite, Chalcosiderite, etc.* (Nos. 332 to 340.)

Andrewsite is a mineral described in 1871 by Prof. Maskelyne, and named after the late Dr. T. Andrews of Belfast.‡ It occurs in small bluish-green globular masses, with a radiate structure, as shown in No. 332. Sir C. Le Neve Foster described its occurrence at Wheal Phoenix Mine, near Liskeard, where it is found in a tin-lode in granite, carrying much limonite and a little copper glance and cuprite.§

A bright green mineral occurring with the Andrewsite of Wheal Phoenix was referred by Prof. Maskelyne to Ullmann's species

\* "Communications from the Oxford Mineralogical Laboratory." *Min. Mag.*, vol. xii. (1900), p. 120. See also Prof. Church in *Journ. Chem. Soc.* [2] vol. viii. (1870), p. 168.

† *Journ. Chem. Soc.* [2], vol. iii. (1865), p. 265.

‡ "On Andrewsite." *Brit. Ass. Rept.* for 1871, p. 75. *Journ. Chem. Soc.* [2] vol. xiii. (1875), p. 586.

§ "On Andrewsite." *Trans. R. Geol. Soc. Corn.*, vol. ix. (1875), p. 163.



*Chalcosiderite*.\* It crystallises in the anorthic system, and the specimens Nos. 333 to 336 show crystals seated on a gozzany matrix. Both chalcosiderite and andrewsite are hydrated phosphates of iron and copper. A trace of uranium has been found in chalcosiderite.

*Henwoodite*, from the same mine, is a mineral named by Mr. J. H. Collins after Mr. W. Jory Henwood (*b.* 1805, *d.* 1875). It occurred in small globular masses of a turquoise blue colour on limonite, and seems to be a hydrous phosphate of copper and aluminium.† Its characters are well seen in Nos. 337 to 340.

## DIVISION 2.

### MINERALS OF CORNWALL AND DEVON.

#### ORES OF LEAD, ZINC, ANTIMONY, ETC.

(Nos. 341 to 408.)

Whilst the tin- and copper-lodes of Cornwall and Devon generally run in a direction which may be roughly set down as nearly E. and W. or N.E. and S.W., those veins which carry lead often take a course nearly at right angles to this direction. Such veins are therefore known as "cross-courses." Many of these cross veins are quite unproductive of ore, whilst others are richly plumbiferous. The N. and S. veins are usually of later date than those which hold an E. and W. course, as attested by the fact that the former may in some cases be seen to cut across and dislocate the latter. The introduction of the lead-ore, probably by means of thermal waters, seems to have been effected subsequently to the deposition of the minerals of the tin-copper lodes. Lead-ore is not confined, however, to the cross-courses, but is sometimes found in the veins which have a bearing more or less approximately east and west. The ore of lead is not infrequently associated with copper-ore, but very rarely indeed with tin-ore. The typical lead-lodes are in killas, and in certain cases at a considerable distance from granite; some of the most productive mines having been in the eastern and northern divisions of Cornwall and the adjacent part of Devonshire, and some even in North Devon. The ore is normally galena, or lead sulphide, and the matrix frequently contains fluor-spar. At the present time but little lead-ore is being raised in Cornwall and none in Devon; and a similar remark applies to zinc-ore, though some of the old burrows, or waste-heaps, may be worked over for sake of the blende.

Ores of zinc frequently accompany those of lead. The zinc usually occurs as sulphide, or zinc blende, and in Cornwall this mineral is rather widely diffused, often in association with lead-ore and not infrequently with copper-ore, though only occasionally with tin.

\* "On Andrews site and Chalkosiderite," *Journ. Chem. Soc.*, [2] vol. xiii. (1875), p. 586.

† *Min. Mag.*, vol. i. (1877), p. 11.

Antimony has been yielded from time to time by many Cornish mines, especially in the northern part of the county, where the killas is remote from granite, but associated in places with greenstone. Up to a recent date small quantities were obtained from this district, but at the present time none is being worked.

*Galena, Cerussite, and Pyromorphite* (Nos. 341 to 380).

In Cornwall and Devon, as in most other lead districts, the common ore of lead is the sulphide, known as *Galena*, a mineral which crystallises in the cubic system, and admits of perfect cubic cleavage. Some excellent examples of crystallised galena are here exhibited, the cubo-octahedra\* of Nos. 343 and 346 being characteristic crystals of this species. But as a larger series of specimens of galena crystals will be found among the minerals from the lead districts of the North of England (pp. 137, 162) no detailed notice is needed in this place.

Many of the specimens here exhibited illustrate the paragenetic relations of galena in the S.W. of England. Chalybite, or ferrous carbonate, is a characteristic companion of galena, and the two minerals may be seen together in Nos. 343 and 345; blende, or zinc sulphide, is another common associate, as shown in No. 348; whilst pyrite, or iron sulphide, is very widely distributed in the lead veins as in the other lodes, and its relation to galena is seen in Nos. 348, 349, 359. With regard to the sparry minerals of the lead veins, the specimens show quartz (345, 349, 354, 359), calcite (349, 357), fluor-spar (351 to 386) and pearl-spar (354). Many of the fine specimens of fluor and galena are from the old silver-lead mines of Beer Alston, in South Devon, which were worked on two great cross courses, or north and south veins, and were once the centre of great mining activity.

The specimen, No. 360, from Wheal Hope, near Truro, shows the well-known pseudomorphous galena sometimes called *blue lead ore*. Here the lead sulphide has gradually taken the place of six-sided prismatic crystals of pyromorphite, or lead phosphate. Such pseudomorphs are, in some cases, hollow, the outer portion of the crystals having been converted into galena, and the enclosed pyromorphite having then been removed in solution. The formation of a sulphide after a phosphate suggests rather exceptional reactions inasmuch as the sulphides are generally of earlier formation than the oxidised compounds of the metal.

Galena readily suffers alteration in the shallow part of an ore-deposit, where the sulphide is exposed to oxygen and carbonic acid, and the most common product of alteration is the carbonate of lead, called *Cerussite*. Examples of this mineral are shown in Nos. 361 to 369. Most of the specimens still retain sufficient of the gozzany matrix to attest the superficial origin of the mineral. The

\* A *cubo-octahedron* is a combination of the two simple forms, the cube and the regular octahedron.



cerussite occurs chiefly in long slender crystals, often acicular and sometimes of great delicacy, and these by their snow-white colour contrast strikingly with the dark brown limonite on which they are displayed. Many of the finest examples are from the old Pentire Glaze Mine, in the parish of St. Minver, in North Cornwall.

A splendid specimen of cerussite from Frank Mill's Mine, Christow, near Exeter—presented many years ago by C. Wescombe, Esq., is exhibited in a neighbouring pedestal-case opposite Wall-case No. 18.

The isomorphous series of phosphates, arseno-phosphates and arsenates of lead, constituting the minerals known as *Pyromorphite* and *Mimetite*, receive ample illustration here (Nos. 370 to 380). Cornwall formerly yielded remarkably fine specimens of these species, and many of the examples in this case came from the old mine of Wheal Alfred, in the parish of Phillack, in West Cornwall—a mine which in its day had great reputation for such specimens. The crystals belong to the hexagonal system, and usually affect a prismatic habit. They exhibit green, yellow and brown colours with a lustre which, in some cases, is rather resinous, and in others almost adamantine, as is so often the case with minerals containing lead. The phosphate or arsenate is associated in pyromorphite and mimetite with lead chloride.

The origin of these species is probably to be sought in the alteration of mispickel and apatite, which has furnished, directly or indirectly, the acid radicles to the lead of the galena. Like the phosphates and arsenates of copper shown in the opposite division of this Case, these lead salts are essentially the products of chemical reactions carried on in the laboratory of the gozzan.

#### *Silver ores (Nos. 381 to 390).*

Most of the galena of Cornwall and Devon is more or less argentiferous, and some of it extremely rich. According to Pryce the ore raised at one time at Garras, near Truro, yielded lead which gave as much as 100 ounces of silver to the ton. The rich argentiferous galena of Beer Alston, in Devonshire, contained from 80 to 120 ounces of silver to the ton of lead, the proportion in one case rising to 140 ounces.

It is probable that the silver in galena occurs as a sulphide, and since the two sulphides,  $\text{Ag}_2\text{S}$  and  $\text{PbS}$ , possess similar crystallographic symmetry they may be associated as isomorphous growths. In some cases, however, they seem to occur rather in the state of mere mechanical mixture, for it has sometimes been found that the galena becomes much less argentiferous after the ore has been well washed.\*

Sulphide of silver, forming the mineral known as *Argentite*, has been found, though rarely, in Cornwall. The mineral crystallises in the cubic system, and the finest British specimens occurred at Wheal Ludcott, an abandoned mine near Liskeard, where the cross course yielded cubo-octahedra measuring half an inch along the edge.

---

\* J. A. Phillips in *Journ. Soc. Arts*, April 27, 1859,

it is from this mine that No. 381 was obtained. No. 382 is a specimen of *Pyrargyrite*, or dark red silver-ore, a sulphantimonite of silver, of rare occurrence in Britain. This specimen came also from Wheal Ludcott. The late Mr. Thomas Davies of the British Museum, described the occurrence of *Stephanite* at this mine—the first recorded occurrence of crystals of this species in Britain.\* This mineral is likewise a sulphantimonite of silver, and was found at Wheal Ludcott, associated with argentite and native silver. Far finer specimens, however, were afterwards obtained from Wheal Newton, near Callington—a mine which yielded the magnificent crystal preserved under a glass shade in Wall-case No. 14. This specimen was the subject of a memoir by Prof. W. J. Lewis.†

In the early part of the last century, silver-ore was discovered in quantity in a cross-course at Wheal Herland, near Gwinear.‡ About 108 tons were extracted from a depth of between 110 and 142 fathoms. The minerals included galena, argentite and native silver, with bismuth and cobalt ore.

Small veins, rich in argentiferous galena and occasionally carrying true silver-ores, have been worked at Duchy Peru in Perranzabuloe. The veins are cross-courses, running north and south, and intersecting the great iron-lode, most of the silver-ore being found near the intersection.§

According to Mr. Joseph Carne, the first discovery of silver in Cornwall was made about 1788, in a mine in the parish of Perranzabuloe, “which was in consequence dignified with the name of Huel Mexico.”||

Dolcoath and Wheal Duchy, near Callington, are other mines which have yielded silver-ore in commercial quantity, the latter mine having produced native silver, argentite and red silver ore, or pyrargyrite.

Silver in a free or native condition has not infrequently been found in Cornish mines, but usually in only very small amount. Several examples of *Native Silver* are here shown (Nos. 383 to 386). The silver is mostly in a capillary form, in thin hairs or stiff wire, often twisted, and occasionally like “moss copper.” It is invariably a secondary mineral, and may have been reduced from the state of sulphide or deposited from silver salts in solution. Prof. Vogt, who has carefully studied the occurrence of native silver at the famous mines of Kongsberg in Norway,¶ believes that direct crystallisation

\* *Geol. Mag.*, vol. iii. (1866), p. 432.

† “On a Crystal of *Stephanite* from Wheal Newton.” *Proc. Camb. Phil. Soc.*, vol. iv. (1883), p. 240.

‡ “Account of the Discovery of Silver in Herland Copper Mine.” By the Rev. Malachy Hitchins. *Phil. Trans.*, vol. xci. (1801), p. 159.

§ “The Duchy Peru Lode, Perranzabuloe.” By Warrington Smyth, M.A., F.R.S. *Trans. R. Geol. Soc. Corn.*, vol. x. (1887), p. 120.

|| *Trans. R. Geol. Soc. Corn.*, vol. i. (1818), p. 121.

¶ “Ueber die Bildung des gediegenen Silbers, besonders des Kongsberger Silbers durch Secundärprocesse aus Silberglanz und anderen Silbererzen.” *J. prakt. Geol.*, April, 1899, p. 113.



from solution is not common, and that the metal has usually passed through the condition of sulphide. Much of the capillary silver in the Cornish veins may possibly have been derived, like the similar forms of native copper, from circulating solutions, through the reducing action of ferrous salts or perhaps metallic sulphides. Haloid combinations of silver are often found native, and in Cornwall the chloride has been recorded from a number of localities. This compound is known commonly as *horn silver*, and technically as *Cerargyrite*—names suggested by the soft and sectile character of the substance, which can be cut as readily as a piece of horn. It crystallises in the cubic system, and is usually found as an incrustation on other minerals. In most of the specimens shown here (Nos. 387 to 390) the cerargyrite is spread over an ochreous matrix, thus testifying to its superficial formation as a mineral of the gozzan. Although rather unattractive to the eye, the mineral is one of the first importance among silver ores, inasmuch as it contains when pure three-quarters of its weight of silver. In Cornwall, however, it occurs generally in only small quantity, but at the present time (1904) a deposit of silver ore, chiefly cerargyrite, is being worked, in a north and south vein, at the Perran Mines, Marazion. No. 387 is a sample of this ore, presented by G. D. McGrigor, Esq.

*Zinc-ores : Blende and Calamine* (Nos. 391 to 403).

As “blende” is a name of rather general significance applied to several minerals, the sulphide of zinc, which is the commonest of all blendes, is termed for distinction’s sake *zinc blende*. The name *Sphalerite*, given to it half a century ago by Haidinger, has been revived in recent years, and is now frequently used in place of “blende.” By miners in Cornwall, as elsewhere, it is often known as *Black Jack*.

As the number of Cornish specimens of blende shown here is not large, and as the mineral will come prominently forward in connection with the products of the North of England, but little need be said in this place with reference to its characters. It crystallises in the cubic system, has usually a dark brown colour, and presents a brilliant lustre. All these characters are illustrated by Nos. 391 to 399. In No. 392 the black blende is crystallised around slender prismatic crystals of white quartz. Chalybite is associated with the zinc ore in No. 400. The iron-bearing variety of blende from St. Agnes, called *Marmatite*, is seen in No. 402. Instead of being crystallised, the blende of Nos. 397 and 401 is in mammillary forms; whilst No. 401 is also exceptional in presenting a white colour.

By exposure to meteoric agencies the sulphide of zinc may become altered to carbonate—thus forming a substance sometimes known to mineralogists as *Calamine*. No. 403 is an example of Cornish calamine. It is not, however, a common mineral in Cornwall and Devon; but the visitor will find it prominent among the ores of the Mendip Hills and of Derbyshire, and further description may, therefore, be deferred until these ores fall under notice (pp. 109, 141).

*Antimony ores* (Nos. 404 to 408).

Antimony—a metal which forms with arsenic and bismuth an alliance of brittle metals—occurs in nature usually as a sulphide, forming a mineral known variously as *Stibnite*, *antimonite*, *grey antimony ore* or *antimony glance*. In some of the cross veins which course in a north and south direction through the killas of north-eastern Cornwall, especially near Padstow and Tintagel, this mineral was at one time not by any means infrequent. The specimen No. 404 is from Endellion. The Cornish stibnite is either massive, fibrous, or in inconspicuous crystals. From such specimens it is refreshing to turn to the noble crystals of this species, which startled mineralogists when they were first brought some years ago from Japan. Of these Japanese crystals a fine example is exhibited in a neighbouring Case, sufficiently illustrating their remarkable size, form and lustre.

In the antimony-bearing veins of Cornwall the metal occurs not only combined with sulphur as stibnite, but associated also with sulphide of lead. The mineral so formed was named by Haidinger, *Jamesonite*, after Robert Jameson who was for so many years professor of mineralogy in Edinburgh (*b.* 1774, *d.* 1854). The specimens 405 to 407 show this species as a fibrous substance of steel-grey or iron-black colour and metallic lustre, not altogether unlike fibrous stibnite. It may be regarded as a sulph-antimonite of lead, or as a double sulphide containing, according to Rammelsberg,  $2\text{PbS} \cdot \text{Sb}_2\text{S}_3$ , having therefore the formula of galena and stibnite.\*

The yellow amorphous mineral in No. 408 is a hydrous lead antimonite, known as *Bindheimite* or *Bleinierite*. It is evidently an oxidation product resulting from the alteration of Jamesonite, with which it is often associated, as seen in Nos. 406 and 407, where the metallic mineral is partially encrusted with the yellow antimonate.

---

\* See, however, a paper by Mr. L. J. Spencer and Mr. G. T. Prior, in *Min. Mag.*, vol. xii. (1900), p. 58.



## CASE IV.

## DIVISION I.

## MINERALS OF CORNWALL AND DEVON.

## SULPHIDES AND SULPHO-SALTS.

(Nos. 409 to 475).

Several metallic sulphides—including those of tin, copper, lead, zinc and antimony—have been already noticed in the descriptions of Cases I. to III., in which they are exhibited. A few other sulphides, such as iron pyrites, with certain sulpho-salts, are grouped together in the Case now under description. Iron-pyrites, the most widely diffused of all metallic sulphides, is not peculiar to any particular type of ore deposit, and has therefore been left without special notice in the preceding pages. The sulpho-salts here exhibited include bournonite, tetrahedrite, and tennantite—and as these species are found usually in lead-veins, and contain antimony and arsenic, they stand in close relationship to the minerals exhibited in the Case immediately preceding (No. III.).

*Pyrite* (Nos. 409 to 428).

*Pyrite* is the name now frequently employed by mineralogists to designate the mineral which is commonly known as *iron-pyrites*. This species consists of iron disulphide, crystallising in the cubic system, and some very bold examples of the crystals are shown in this Case. In the mineral-veins of the West of England, pyrite is one of the commonest constituents, and is termed by the miners *mundic*. According to Borlase “the Cornish name is Mundic, from the cleanly shining appearance both of its surface and structure.”\*

Pyrite is a mineral widely distributed through most rocks, whether eruptive or sedimentary, in some cases as an original mineral, in others as a secondary product. As a vein-mineral its formation appears to have extended from the earliest to the latest stages in the history of the lode. In some cases the pyrite may be of primary origin; in others it has been introduced at a later date, evidently deposited from solution on other minerals, encrusting or replacing them, as witnessed by such pseudomorphs as Nos. 426 and 427; and in yet other cases the pyrite may be of comparatively recent

---

\* “The Natural History of Cornwall.” Oxford: 1758, p. 131.

origin, due to the reduction of solution of a sulphate, though probably this mode of origin is not so common in veinstones as in sedimentary rocks. Stalactitic pyrite has occurred at East Pool.

Nos. 414 and 415 show the pyrite crystallised on quartz, whilst in No. 410 the quartz has crystallised on the pyrite. In No. 425 pyrite has been deposited on large cubes of fluorspar, forming a brass-like coating with a drusy surface. No. 426 is a hollow *epimorph* of pyrite after calcite, and No. 427 one of pyrite after baryte; the mineral originally invested having in both cases been completely removed, leaving a pyritous shell.\*

Pyrite commonly crystallises in cubes, as shown in Nos. 410, 415 and 416. In No. 410 the cubes measure more than an inch along the edge. The fine specimen No. 409 shows the regular octahedron in combination with the cube. No. 413 is an excellent example of sharply defined crystals in form of the pentagonal dodecahedron, which is a hemihedral form of the four-faced cube, so characteristic of pyrite that it was called by Haidinger the *pyritohedron*. A hemihedral form of the six-faced octahedron is known as the *dyakis-dodecahedron*, or *diplohedron*; this is also characteristic of pyrite, but though occasionally occurring as an independent form it is usually found in combination. The "Pyrites group" consists of a few closely allied minerals, assuming these hemihedral forms; and since each face of the pentagonal and the *dyakis-dodecahedron* has an opposite parallel face the group is said to present "parallel faced hemihedrism."†

Most of the specimens exhibited in this Case show the brass-yellow colour of the pyrite, but in No. 419 the colour is steely grey. The metallic lustre is illustrated by most of the specimens, and in No. 414, where the pyrite is crystallised on quartz, the lustre is exceptionally brilliant. Occasionally the surface becomes coated with a brown tarnish due to superficial alteration into limonite. Such alteration may penetrate to a considerable depth, and ultimately the entire crystal may be converted into the brown iron oxide. This change—one of the most common chemical changes which pyrite suffers—is well illustrated by the specimen No. 428, in which an aggregate of cubes has been transformed more or less completely into ferric hydrate with retention of the pyrite shape. The limonitisation of pyrite contributes largely to the formation of gozzan.

Still more unstable than pyrite is the ortho-rhombic species of iron disulphide, known as *Marcasite* (No. 428). This mineral occurs occasionally in the Cornish veinstones, but is not usually abundant, and further reference to it is therefore deferred until the *marcasite* of the sedimentary rocks has to be described (p.198).

\* An *epimorph* is a pseudomorph formed by the deposition of one mineral upon another; and is therefore simply a mechanical encrustation. Epimorphs are known also as *perimorphs*.

† See Prof Miers's "Mineralogy" (p. 49) for technical definition of the class of crystals known as the "Pyrite class," characterised by "tesseral centro-symmetry."



A fine series of specimens of pyrite will be found in Case II. of the Ludlam Collection in the Hall of the Museum, and others in the Wall-case No. 46 on the Principal Floor.

*Mispickel* (Nos. 429–436).

Although *Mispickel* has already been noticed as an associate of tinstone (p. 31), it demands further reference in this place, as being an important member of the group of metallic sulphides known sometimes as the *Pyritoids*. In a pure state it is an arseno-sulphide of iron, conforming to the simple formula  $\text{Fe As S}$ , and therefore containing theoretically about 46 per cent. of arsenic. Hence it is known as *arseno-pyrite* or *arsenical pyrite*. Struck with the pick it emits the characteristic garlic-like odour of arsenic, and is recognised by miners as *arsenical mundic* or *arsenical iron*, or merely as “*arsenic*.” *Mispickel* belongs to the orthorhombic system, like marcasite, with which it seems to be isomorphous. Many specimens, as Nos. 429, 430, show the rhombic prisms sharply defined, and some illustrate the characteristic twinning, similar to that of marcasite. The curvature of some of the faces is very marked in No. 429. The silver white and steel-grey colours of mispickel are fairly illustrated by Nos. 430, 434; but after exposure, though less prone to alteration than marcasite, the colour is apt to suffer. The bold crystals in No. 433 show a brilliant reddish tarnish: this specimen is from Wheal Kitty, St. Agnes, and the mineral is here associated with copper pyrites, coated with green carbonate, whilst chalybite, in globular aggregates of lenticular crystals, has been deposited on certain faces of the mispickel.

Many of the specimens show the mispickel in association with quartz, in some cases well crystallised. The quartzose veinstone of certain specimens, as seen here, is of cavernous structure, with pseudomorphic hollows; in other cases it is “peachy,” that is to say, it is associated with chlorite. Copper-pyrites may be detected on several specimens.

By the alteration of mispickel, through the action of oxidising agencies in the shallow parts of a lode, iron arsenates, like scorodite, may be formed (p. 73). When the arsenide is associated with copper ores, as is so often the case, as just mentioned, the resulting products of oxidation may be copper arsenates, or copper-iron arsenates, such as are illustrated by the fine display in Case III.

The importance of mispickel as an “arsenic ore,” or source of white arsenic, in the copper and tin mines of the West of England, has already been referred to, and statistics of production given, at p. 32.

*Bournonite* (Nos. 437 to 456).

More than a century ago, the beautiful mineral now called *Bournonite* was figured by Mr. Rashleigh in his work on the Menabilly Collection\*—a collection recently added to the Museum of the

\* \* Rashleigh's “Specimens of British Minerals,” 1797 Pl. xix. figs. 1 and 2, p. 34.

Royal Institution of Cornwall at Truro. His specimens were obtained from Wheal Boys, in the parish of Endellion, in the killas country of North-east Cornwall. It was from this locality that the specimens here shown as Nos. 437 and 438 were derived. The mineral occurred there in association with zinc blende, jamesonite, chalybite, etc.

Described by Rashleigh as "an ore of antimony" it was recognised as a distinct species by the Comte de Bournon, a French refugee living in this country in the early part of the eighteenth century.\* By de Bournon it was called from its locality *endellione*, whence the name *Endellionite*, sometimes applied to this species. This name, however, has generally given place to Jameson's name bournonite, in recognition of the mineralogist who first described it with accuracy.

The original specimens from Endellion were eclipsed by the much finer examples raised many years ago at Herodsfoot Mine, about seven miles S.W. of Caradon in East Cornwall. In this silver-lead mine, the loderan through killas, with a bearing about 20° E. of north, and the argentiferous galena for which the mine was worked occurred in a quartz veinstone, where it was associated with pyrite, blende, occasional bunches of rich copper ore, and certain antimonial minerals. The antimony ore occurred just below the gozzan, and being detrimental to the lead was regarded as a nuisance.†

An analysis of the Herodsfoot bournonite by Mr. C. E. Wait‡ showed that it conformed to the recognised formula  $\text{Cu}_2\text{Pb}_2\text{Sb}_2\text{S}_6$ ,§ the antimony being replaced to a small extent by arsenic. It may be regarded as a sulphantimonite of lead and copper.

Bournonite crystallises in the orthorhombic system; and some noble crystals, remarkable not only for size but for complexity of form and brilliancy of certain faces, are exhibited in this Case. The crystallography of the Cornish bournonite has been exhaustively studied by Professor Miers.|| Twin groups are very common, giving rise in some cases to cruciform, stellate and circular discs, which are known as *cog-wheel-ore*, as illustrated by Nos. 441, 442, 445 and 446.

A hint as to the possible genesis of bournonite may be obtained from certain pseudomorphs having the form of tetrahedrite but the composition of bournonite, thus suggesting that under certain circumstances bournonite may have been derived from the alteration of tetrahedrite.

\* "Description of a triple sulphuret of Lead, Antimony and Copper from Cornwall." By the Count de Bournon, F.R.S. *Phil. Trans.*, vol. xciv. (1804), p. 30. Also Analyses by Hatchett, *Ibid.*, p. 63.

† "On the Metalliferous Associations of the Liskeard Rocks." By Mr. John Giles. *Trans. Roy. Geol. Soc. Corn.*, vol. vii. (1865), p. 198.

‡ "Analysis of Bournonite." *Chem. News*, vol. xxviii. (1873), p. 271.

§ This is equivalent to  $2\text{PbS} \cdot \text{Cu}_2\text{S} \cdot \text{Sb}_2\text{S}_3$ .

|| "The Crystallography of Bournonite." By H. A. Miers, M.A., *Min. Mag.*, vol. vi. (1884), p. 59.



*Tetrahedrite and Tennantite* (Nos. 457 to 475).

*Tetrahedrite* is known sometimes as *grey copper ore*, but this term is ambiguous since it is also occasionally applied to copper glance. The name *tetrahedrite* refers to the regular tetrahedral form which the crystals usually present. Grand examples were obtained at one time from Herodsfoot Mine, where the mineral occurred in association with the bournonite just described. A fine suite of the Liskeard *tetrahedrites* is here exhibited (Nos. 457 to 468). The regular tetrahedron is usually bevelled on the edges by planes of the three-faced tetrahedron. It will be noted that the crystals are coated in most cases with minute crystals of *chalcopyrite*, producing a rough drusy surface; and that the *chalcopyrite* frequently displays a brilliant iridescence, due to superficial conversion into "peacock copper." When the mineral was first raised the colours were often gorgeous, but the effect became impaired by exposure. The encrusting copper-pyrites seems to have been derived from the alteration of the *tetrahedrite*.

The chemical composition of *tetrahedrite* is very complicated, and the crystals are often wanting in homogeneity; but it may be regarded as essentially a *sulphantimonite* of copper, in which the copper is partially replaced by iron, zinc or even silver, whilst the antimony is more or less replaced by arsenic. Recent analyses by Mr. G. T. Prior\* have led to a new formula, which admits of simplest expression in the form  $\text{Cu}_3\text{SbS}_4$ .

*Tetrahedrite* is likewise known under the name of *fahl ore*—a name borrowed from the German *Fahlerz*, which is now regarded as a general term applied not only to the copper *sulphantimonite* but also to the corresponding *sulpharsenite*. When arsenic is substituted for antimony, the mineral is called *Tennantite*. The old name *fahl-ore* consequently includes both *tetrahedrite* and *tennantite*, with isomorphous mixtures of the two. In some *tennantite* bismuth is present. *Tennantite* received its name from a famous English chemist, *Smithson Tennant* (b. 1761, d. 1815). The specimens Nos. 469 to 475, from Wheal Jewel in Gwennap, illustrate the characters of this mineral, and show its association with quartz and copper pyrites.

Excellent crystals of *tetrahedrite*, having all the characteristics of the Cornish mineral, were found on the ancient Roman bronze coins which Daubr  e described, from the thermal springs of Bourbonnelles-Bains (Haute Marne). The alteration of the bronze yielded not only *tetrahedrite*, but also *chalcosite*, *chalcopyrite* and *erubescite*.

No. 476 is a specimen of *Condurrite*, a mineral described by Faraday, from the Condurrow Mine, Camborne. It is a black amorphous mineral, so soft as to soil the fingers. Chemically it is chiefly a copper arsenide, but seems to be a mixture rather than a definite species, and has been regarded as an alteration-product derived perhaps from *tennantite*.

---

\* "The Identity of Binnite with Tennantite; and the Chemical Composition of Fahlerz." By G. T. Prior, M.A., and L. J. Spencer, M.A. *Min. Mag.*, vol. xii. (1900), p. 184 (*Fahlerz*, p. 193).

## DIVISION 2.

## MINERALS OF CORNWALL AND DEVON.

## ORES OF IRON, ETC.

(Nos. 477 to 544.)

Ores of iron enjoy a wider distribution than the ores of any other metal. They occur both in eruptive and in sedimentary rocks and are not restricted in the latter to any special horizon. Nevertheless, in Cornwall and Devon, the accumulation of suitable minerals in the form of workable ore-bodies is rather limited; and at the present time no iron ore is being raised in Cornwall, and only an insignificant quantity in Devonshire.

Most of the fine specimens exhibited in this Case were obtained many years ago from the famous mine near Lostwithiel, which was known, after Queen Victoria's visit in 1846, as the Restormel Royal Iron Mine. The great iron lode, generally in two branches, is a cross course in killas, bearing about  $15^{\circ}$  W. of N., and having a dip to the east of between  $70^{\circ}$  to  $85^{\circ}$ .\* The branches formed practically two parallel veins, the principal lode being in some parts more than 20 feet wide. The ore was carried in a quartzose veinstone, which abounded in vugs or drusy chambers, often lined with beautiful crystals.† It was from the walls of such cavities that the specimens here exhibited were taken. The ore was chiefly hæmatite, with göthite and limonite, accompanied occasionally by black oxide of manganese and lithomarge, in small pockets.

Extensive workings for iron-ore were also made in Cornwall on the Great Perran Lode, or the Duchy Peru lode, in Perranzabuloe. This vein extends for several miles in a direction which is approximately W.N.W. and E.S.E., and has in some parts a width of as much as 120 feet. The lode courses through killas, and consists principally of a brecciated quartzose veinstone holding much chalybite, or carbonate of iron, which passes into brown iron-ore in the upper part and is associated with large quantities of zinc blende and a little copper-ore.‡ Both in this lode, and in the Restormel iron-lode, pseudomorphous quartz is abundant, testifying to the chemical changes which must have been rife since the original formation of the veins.

*Magnetite (No. 477).*

Two anhydrous oxides of iron occur native—one called magnetite ( $\text{Fe}_3\text{O}_4$ ), comparatively rare in this country; the other termed hæmatite ( $\text{Fe}_2\text{O}_3$ ), fairly abundant, and in the North of England largely worked as an ore.

\* Henwood, *Trans. R. Geol. Soc. Corn.*, vol. v. (1843), p. 128.

† A *drusy* surface is one coated with small crystals. A cavity lined with crystals is known as a *druse*; or if rounded it is often termed a *geode*.

‡ See Sir W. W. Smyth's papers, "On the Iron Mines of Perran." *Trans. R. Geol. Soc. Corn.*, vol. vii. (1865), p. 332; and "The Duchy Peru Lode, Perranzabuloe." *Ibid.* vol. x. (1887), p. 120.



*Magnetite* occurs as a constituent of nearly all eruptive rocks and is especially notable in the dark-coloured dense rocks of basic type. It must have separated from the molten magma in most cases, at an early phase in the consolidation, for it occurs as enclosures in nearly all the other rock constituents. This priority of crystallisation, however, was not invariable; and Dr. Teall has shown, for example, that in some of the basaltic rocks of Franz Josef Land the magnetite was the last mineral to crystallise.\*

Whilst magnetite is thus abundant in microscopic crystals and grains, it is by no means common, in this country, in macroscopic crystals. No. 477 shows, rather exceptionally, some bright little octahedra of Cornish magnetite. Strings of magnetic iron-ore occasionally seam the rocks of the south-western counties, and declare their presence by disturbing the compass of a passing tourist. In South Devon such ore is sometimes found in quantity sufficient to invite exploration. Sir C. Le Neve Foster has described the iron-ore of Haytor, on the eastern border of Dartmoor, as occurring in the form of thick beds of magnetite, interstratified with altered shales and sandstones of Carboniferous age.† The formation of the magnetite by metamorphism of other ores may be connected with the intrusion of a mass of granite. The surrounding rocks are much silicified and contain hornblende, garnet, axinite and some other minerals. There are three beds of ore, with an aggregate thickness of 26 feet.

In describing the bedded deposits of iron ore at Smallacombe, in Devonshire, Mr. J. H. Collins has expressed his opinion that the ore was originally a carbonate of iron which has become altered to magnetite by the action of circulating waters.‡ It is well known that iron ore carrying the metal as carbonate, such as spathic ore or even clay ironstone, becomes magnetic on calcination; and it is not unlikely that magnetite may in some cases be formed from chalybite by contact with basalt or other rocks at even moderate temperature.

Magnetite may likewise result from the deoxidation of hæmatite by means of ferrous compounds or other reducing media. Pure hæmatite contains 30 and magnetite 28 per cent. of oxygen; so that the transformation does not necessitate a great amount of deoxidation. On the other hand, pseudomorphs of hæmatite after magnetite show that the converse change may take place. *Martite*, which is a red oxide of iron in crystals like those of magnetite, has probably such an origin. If not a pseudomorph,  $\text{Fe}_2\text{O}_3$  must be dimorphous.

On the disintegration of the crystalline rocks, the magnetite which they contain tends, by its density and comparative stability, to accumulate locally in the detritus. Hence the origin of the black

---

\* "Notes on a Collection of Rocks and Fossils from Franz Josef Land." *Quart. Journ. Geol. Soc.*, vol. liii. (1897), p. 477.

† "Notes on Haytor Iron-mine." *Quart. Journ. Geol. Soc.*, vol. xxxi. (1875), p. 628.

‡ *Rep. Min. Assoc. Corn.*, 1872.

magnetic sand found on the Cornish coast, as near Botallack. Such sands may contain also titaniferous iron ore or *Iserine*. A similar mineral called *Menaccanite* takes its name from Menaccan, near Helston in Cornwall, where it was found as sand in a stream at Tregonwell Mill.

*Hæmatite* (Nos. 478 to 481).

Under the name of *Hæmatite* are included all the varieties of native ferric oxide, which are either crystallised in the hexagonal system or are merely massive. The crystals have often the brilliancy of burnished steel, whence the name *specular iron*, *iron glance* or *looking glass ore*. This splendid lustre may be seen on the small crystals here exhibited (Nos. 478 to 480). Most of these are from Botallack Mine, and show the specular mineral implanted, as in many other localities, on quartz. In No. 479 the mineral is associated with fine bisphenoids of chalcopyrite on hexagonal prisms of quartz. The mines of Cumberland yield crystallised specimens of this mineral so much finer than anything found in the Cornish mines that fuller description of the substance may be fairly deferred until the North of England minerals are noticed (p. 144).

A variety of specular hæmatite occurring in very fine scales is known as *micaceous iron ore*. Such a mineral occurs in Devonshire, near Bovey Tracey, and it is recorded that large quantities were sent to London, "in the days of pounce,"\* and sold as *Devonshire sand*. In recent times considerable quantities have been raised in Devonshire under the name of "*shining ore*," and exported to Germany. The specimen No. 481 shows the character of the substance. It is rather like finely divided plumbago, and may be used as a lubricating agent, but it is probably employed mostly as a pigment for iron-work. It occurs in narrow lodes in granite.†

Of massive hæmatite or *red iron ore*, specimens from Restormel may be seen in Nos. 493 to 495, which show the mineral associated with the hydrated oxides—göthite and limonite. In some cases hæmatite may have been derived from such hydrates by natural removal of water; but the converse change, the hydration of red ore, is also frequent. Mr. Solly has described pseudomorphs of hæmatite after pyrite from Torquay.‡ The conversion of the sulphide into limonite is common enough, but its alteration to hæmatite is exceptional, and it is suggested that the hæmatite was there formed by the reaction of limestone on ferric chloride, due to the alteration of the pyrites by sea water.

\* "The Economic Geology of Devon," By R. N. Worth. *Trans. Devon Assoc.*, vol. vii. (1875), p. 225. De la Beche's Report on Cornwall, p. 617.

† "Micaceous Iron-ore, near Bovey Tracey." By Mr. Joseph S. Martin. *Trans. March. Geol. Soc.*, vol. xxiii (1895), p. 162.

‡ "Pseudomorphs of Hæmatite after Iron Pyrites." By R. H. Solly, M.A., with an analysis by A. Hutchinson, B.A. *Min. Mag.*, vol. viii. (1889), p. 183.



*Göthite and Limonite (Nos. 482 to 500).*

The specimens Nos. 482 to 492 present a fine series of specimens of *Göthite*, a rather rare mineral, of which Cornwall has furnished typical examples, of exceptional beauty. This mineral is composed of peroxide of iron with about 10 per cent. of water, or it may be regarded as ferric hydrate or hydrate of iron. It crystallises in the orthorhombic system, and good crystals are shown from Botallack and St. Just as well as from Restormel. Its occurrence in acicular crystals, forming fibrous aggregates, has led to the name *needle iron ore*: the uniform mass No. 992 exhibits this fibrous structure. In No. 491 the surface presents a velvety appearance, rather like that of the Bohemian variety, which is known from this character as *Sammelblende*. The name göthite, given to this mineral a century ago in honour of the poet, recalls the interest which he took in mineralogy, as in other branches of natural history.

The association of göthite with other minerals in a regular succession of deposits is beautifully illustrated by the specimens Nos. 493 to 496 from the Restormel Royal Iron Mine. The sequence shows (1) crystallised quartz, (2) fibrous limonite or wood iron ore, (3) crystalline göthite, (4) compact hæmatite. These minerals have evidently been deposited in regular succession on the walls of a vug or cavity in the veinstone, and the successive zones are sharply separated from each other by differences of colour—white, brown, black and red—almost as marked as in the banded deposits of an agate.

*Limonite*, or *brown iron ore*, is a hydrated oxide of variable composition, conforming in the purest varieties to the formula  $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ , thus differing from göthite,  $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$ , by containing nearly 5 per cent. more water. Unlike göthite, it never occurs in distinct crystals, but fibrous forms are not uncommon. Some beautiful examples of this *wood iron ore*, or fibrous limonite with radial and zonal structure, hair-brown in colour and silky in lustre, are shown in the Restormel specimens Nos. 498 and 499. Limonite frequently occurs in stalactitic forms, clearly pointing to its deposition from water; and a specimen of this character, numbered No. 497, is interesting in that the surface of the stalactites is sprinkled over with small crystals of native copper. No. 500 is an example of the ochreous limonite, of yellowish-brown colour and loose texture, known as *bog iron-ore*—evidently a superficial deposit of recent origin. The brown iron ores will receive further notice in the description of the minerals of the sedimentary rocks (see p. 193).

In mineral-veins where pyrites and chalybite are common, as in Cornwall and Devon, the formation of limonite, and of other oxides and hydroxides of iron, presents no difficulty, inasmuch as they are evidently minerals of secondary origin, and so unstable a body as pyrites may well have been, in many cases, their original source; whilst in other cases the oxides may have resulted from the alteration of carbonate of iron.

*Chalybite* (Nos. 501 to 516).

Iron occurs in the lodes of the West of England not infrequently in the form of carbonate, constituting the mineral known as *Chalybite* or *Siderite*. This mineral crystallises in the rhombohedral system; carbonate of iron taking its place with the carbonates of calcium, magnesium, zinc, and manganese, in the isomorphous group of rhombohedral carbonates.

Cornwall is rather famous for its crystallised chalybites, and an excellent and extensive collection is here exhibited. The crystals are usually of rhombohedral habit, and not of very complex form. Acute rhombohedra occur in some specimens, and the basal plane is a feature in others. Certain crystals simulate the appearance of regular octahedra. No. 513 is a characteristic example of lenticular chalybite, the obtuse rhombohedra having curved faces; whilst No. 514 shows the mineral in a fibrous form.

Dr. A. Hutchinson has recently examined the chemical composition and optical characters of a series of well crystallised specimens of chalybite from near Camborne, now in the mineralogical museum of the University of Cambridge.\* According to Prof. Noel Hartley and Mr. Ramage, the chalybite of East Pool Mine contains such rare metals as indium and rubidium, with cobalt, nickel, bismuth, etc.†

Well known to collectors, but now extremely rare, are the zoned crystals of chalybite, found at one time at Wheal Maudlin, near Lostwithiel, represented by No. 512, and also by several fine specimens in the Ludlam collection in the Hall, Case VI. They are hexagonal crystals of tabular habit, seated on quartz from the walls of a geode, and are remarkable for the fact that the basal plane, which is slightly curved, displays a series of zones of various shades of brown, forming concentric hexagons.

The association of chalybite with copper pyrites is seen in No. 503, with fluorspar in Nos. 507 and 508, and with quartz in many specimens such as Nos. 501, 506, 509, and 511. In No. 510 the chalybite is crystallised on a group of prismatic crystals of quartz.

Much history may be read in such a specimen as No. 515, from Virtuous Lady Mine (afterwards the Bedford United Mines), near Buckland Monachorum, in South-western Devonshire. This is one of the well-known "boxes." It is evident that this was originally a large cubic crystal of either fluorspar or iron pyrites, probably the former, since this mineral not infrequently assumes such bold cubic forms.‡ Upon this cube there was deposited, from solution, a rather thick coating of crystalline chalybite. Then the fluorspar was dissolved out, leaving a hollow shell of carbonate of iron. Into this

\* "The Chemical Composition and Optical Characters of Chalybite from Cornwall." By A. Hutchinson, M.A., Ph.D. *Min. Mag.*, vol. xiii. (1903), p. 209.

† *Journ. Chem. Soc.*, vol. lxxi. (1897), p. 533.

‡ Traces of fluor have been found in some of the hollow cubes.



cubic "box," silica was introduced, and formed a group of prismatic crystals of quartz on one of the inner walls. Finally, there was deposited upon this quartz some bold bisphenoids of copper pyrites, now superficially tarnished.

It must be admitted that as ferrous carbonate is rather soluble in most waters it is not easy to understand the nature of the solvent which could remove fluorspar whilst leaving the chalybite unattacked.

In addition to the boxes, Virtuous Lady Mine yielded a number of other hollow epimorphs, which from their shape were called "slippers." No. 516 is an example. Here the nature of the original mineral is uncertain; but though selenite has been suggested, it was more probably tabular barytes. The mineral, whatever its nature, became encrusted with chalybite, and was then removed, leaving a pseudomorphous hollow. The surface of the chalybite in this specimen is brightened by a partial sprinkling of iron pyrites.

Several other examples of these interesting epimorphs, including some much larger than those shown here, will be found in the Wall-case No. 33, on the opposite side of the Principal Floor.

Experiment shows that carbonate of iron may be precipitated in rhombohedral crystals, not unlike those of chalybite, by the reaction of an alkaline carbonate on ferrous sulphate. Such a sulphate, resulting from the oxidation of pyrites, is common in mine waters, whilst carbonates are carried in all surface drainage, and in underground waters circulating throughout the zone of oxidation. In some cases, however, the chalybite occurs at considerable depths in mineral-veins.

Ferrous carbonate is not characterised by great stability, and tends to pass, under the influence of air and water, into the condition of ferric hydrate: hence the deep brown colour on the external part of many chalybite crystals. If manganese be present, as it often is, the coating may become nearly black.

#### *Vivianite* (Nos. 517 to 524).

*Vivianite* is a mineral which was originally named by Werner after J. G. Vivian, who discovered it in Cornwall. Some very fine crystallised specimens are here exhibited. The crystals belong to the monoclinic system, and offer perfect cleavage parallel to the clinopinacoid. Most of the specimens show a fine indigo-blue colour; but it is probable that pure vivianite, which is a hydrous ferrous phosphate, is colourless, and that the blue tints are developed by some of the iron passing, on exposure, into the ferric condition. Analyses of Cornish vivianites have been published by Prof. Maskelyne.\*

Most of the specimens shown here were obtained from Wheal Jane, near Truro, and show the vivianite associated with quartz, pyrite, mispickel, and chalybite. Two cleavable masses, exhibiting

---

\* "Mineralogical Notices," By Prof. N. Story-Maskelyne and Dr. Walter Flight. *Journ. Chem. Soc.*, [2] vol. ix. (1871), p. 6.

the foliated structure of the mineral, are in the tray No. 524. In No. 520 a thin flat blade of blue vivianite appears to impale a crystal of quartz; the quartz having been deposited around a pre-existing crystal of the phosphate.

The soft pulverulent nodular mass of vivianite in the tray No. 524 represents the *blue iron earth*, not infrequently found in peat mosses, with bog iron ore. This earthy vivianite is often very pale, nearly white, when first dug up, and acquires its Berlin blue colour by exposure. When found with fossil bones, by no means an uncommon association, its origin is obvious.

*Ludlamite, etc. (Nos. 525 to 529).*

In 1876 the late Mr. Frederick Field gave the name of *Ludlamite* to a new Cornish mineral, in compliment to Mr. Henry Ludlam, whose extensive collection of minerals passed into the possession of the Museum of Practical Geology, by bequest, in 1880. A fine series of specimens is here exhibited.

Ludlamite is a green transparent mineral, crystallising in the monoclinic system, and consisting, according to Mr. Field's analysis, of a hydrous ferrous phosphate. The crystallography of the mineral was studied by Prof. Maskelyne.†

The specimens of ludlamite here shown were obtained by Mr. Talling from Wheal Jane, in the parish of St. Kea, near Truro. The associated minerals, as seen in most of these specimens, include quartz, chalybite, vivianite, pyrite and mispickel. The conditions of occurrence are indeed identical with those of the vivianite, exhibited alongside these specimens. The two iron phosphates have, however, certain characters by which they are readily separated, such as the colour and the habit of the crystals.

Moreover, on exposure to heat, ludlamite decrepitates and breaks up into brilliant crystalline plates of an intense bluish green colour, whereas vivianite similarly treated turns white and exfoliates.

The mineral called *Dufrenite*, in honour of the French mineralogist Dufrenoy, is represented by No. 529—a specimen from Wheal Phoenix, near Liskeard. This is a hydrous phosphate of iron, which has been analysed by Prof. Kinch.‡

*Childrenite (Nos. 530 to 532).*

The rare mineral *Childrenite* was first described by Lévy, from specimens discovered at the beginning of the nineteenth century in cutting a canal near Tavistock in Devonshire. Soon afterwards it was found at Crinnis Mine, near St. Austell, where it occurred in

\* "On Ludlamite, a new Cornish Mineral." By F. Field, F.R.S. *Phil. Mag.*, [5] vol. iii. (Jan. 1877), p. 52. Also *Proc. Cryst. Soc.*, part i (1877), p. 23.

† "Note on the Optical Characters of Ludlamite." By N. S. Maskelyne, M.A., F.R.S. *Phil. Mag.*, Feb. (1887), p. 135.

‡ "On a New Variety of Mineral from Cornwall." By Prof. E. Kinch and F. H. Butler, M.A. *Min. Mag.*, vol. vii. (1887), p. 65. "On Dufrenite from Cornwall." By Prof. E. Kinch. *Ibid.*, vol. viii. (1889), p. 112.



association, with apatite—an association not without suggestiveness, seeing that childrenite is also a phosphate. Many years passed without any fresh discovery, and it remained a mineral of great rarity until the late Mr. Talling re-discovered it near Tavistock, and afterwards in larger crystals at the George and Charlotte Mine, between Tavistock and Callington. It has also been found at Wheal Crebor and at the Devon and Cornwall United Mines.

All the specimens here exhibited are from the neighbourhood of Tavistock, and show the mineral accompanied by chalybite, pyrite, quartz and chlorite. Childrenite is a hydrated phosphate of iron and aluminium, often with manganese.\* It occurs in brilliant little crystals of pyramidal habit, belonging to the orthorhombic system, and presenting a yellow or brown colour which gives it rather the appearance of chalybite, from which it differs, not only in crystalline form, but in greater hardness. A closely allied mineral found at Branchville, Fairfield Co., Conn., U.S.A., has been described by Profs. Brush and Dana under the name of *Eosphorite*.† It contains, however, much more manganese and less iron than childrenite.

The name childrenite, given originally by Lévy, was complimentary to Mr. John George Children, who was for many years an officer of the British Museum, first in the department of antiquities and afterwards in that of zoology, and who was at one time Secretary of the Royal Society (b. 1777, d. 1852).

*Pharmacosiderite* (Nos. 533 to 536).

In William Phillips' paper on Cornish cuprite, published by the Geological Society in 1811,‡ the author describes and figures the "arseniated iron," which came afterwards to be called *Pharmacosiderite*, a name proposed by Hausmann in consequence of the poisonous character of the arsenic (*φάρμακον*, *pharmakon*, poison). The mineral is easily recognised by its occurrence in small sharply defined cubic crystals, of green colour, whence the name *cube ore*, often applied to this species. The Cornish *pharmacosiderite* had previously been noticed by the Comte de Bournon,§ and an imperfect analysis, probably of an impure specimen, was published by Chenevix.||

The mineral may be regarded as a hydrated ferric arsenate, and the specimens here exhibited show, by their occurrence on gozzan, that it is an alteration product formed in the upper part of the veins, and therefore may be of comparatively recent origin. A very careful

\* An analysis by Prof. Church will be found in *Journ. Chem. Soc.*, [2] vol. xi. (1873), p. 103.

† *Am. Journ. Soc.*, xvi. (1878), p. 35.

‡ *Trans. Geol. Soc.*, vol. i. (1811), p. 23.

§ "Description of the Arseniates of Copper and of Iron, from the county of Cornwall." By the Count de Bournon. *Phil. Trans.*, vol. xci.

|| "Analysis of the Arseniates of Copper and Iron, described in the preceding paper." By Richard Chenevix, Esq. *Ibid.*, p. 193. [*Pharmacosiderite*, p. 218.]

re-examination of the mineral has been made by Mr. E. G. J. Hartley, in the Oxford Mineralogical Laboratory;\* and from his analyses it appears that potash is an essential constituent of the mineral, though it may be present in only small quantity. Mr. Hartley has observed that if a green crystal of pharmacosiderite be placed for a few minutes in a solution of ammonia, its colour changes to red, but is restored to green by the action of dilute hydrochloric acid.

*Scorodite, etc. (Nos. 537 to 541).*

Another arsenate of iron has been called *Scorodite*, in consequence of the garlic-like odour of arsenic, emitted by the mineral on exposure to heat (*σκόροδον*, *skorodon*, garlic). In No. 537 the two arsenates, pharmacosiderite and scorodite, are seated together on the gozzan of Wheal Gorland. The two minerals, though allied chemically, present marked physical differences; for whilst the one occurs in dark green cubes the other forms pale bluish-green translucent crystals, belonging to the orthorhombic system, and usually aggregated in small globular groups, with a diverging structure. Scorodite was regarded by the older mineralogists as an arsenate of copper—a pardonable enough error, due to its colour and to its occurrence, with copper arsenates in the St. Day district. Cornish specimens sometimes show the scorodite on a matrix containing mispickel, and this association at once discloses the genesis of the mineral. Simple oxidation and hydration of the arsenide might readily result in the formation of scorodite.

Scorodite occurs as a deposit from several of the hot springs and geysers of the Yellowstone Park, forming in some cases a brilliant green incrustation on the siliceous sinter. In this form the scorodite is a very unstable substance, readily undergoing decomposition and leaving an ochreous residue which contains more or less arsenic acid.†

The rare species *Liskeardite*, from near Liskeard, described by Prof. N. S. Maskelyne,‡ is represented by a single specimen No. 541. The mineral is a hydrated arsenate of aluminium and iron, and occurs at Marke Valley as an incrustation, associated with scorodite and mispickel—two minerals which suggest its origin and relationship.

*Cronstedtite (Nos. 542 to 544).*

Several examples of the rare mineral *Cronstedtite* are here exhibited from Wheal Jane, near Truro, where the conditions of its occurrence, judging from the specimens, are similar to those under which the vivianite and ludlamite occur (p.70).

\* *Min. Mag.*, vol. xii. (1900), p. 152.

† "Notes on the Deposition of Scorodite from Arsenical Waters in the Yellowstone National Park." By Arnold Hague. *Am. Journ. Sc.*, [3] vol. xxxiv. (1887), p. 171. *Journ. Chem. Soc.*, vol. liv. (1888), p. 122.

‡ *Nature*, vol. xviii. (1878), p. 426. *Journ. Chem. Soc.*, vol. xliii. (1883), p. 140.



**Cronstedtite**—a mineral which borrows its name from a Swedish chemist, Axel Frederic Cronstedt (*b.* 1722, *d.* 1765)—may be regarded as a hydrous ferroso-ferric silicate. It occurs in small black lustrous crystals, referable to the hexagonal system, and remarkable for the hemimorphism which they frequently present—the two extremities of the crystals having dissimilar terminations. In the specimens here shown, the mineral is mostly in radiating groups of acicular crystals, rather suggestive of schorl, but the substance is much softer. In No. 542 the little slender crystals are disposed in stellate aggregates, after the fashion of some schorl, and these repose on chalybite, which itself is spread over pyrite, at the expense of which it has evidently been formed. In No. 543 the stellate cronstedtite is associated with chalybite and a little limonite on pyrite. No. 544 shows a veinstone with copper pyrites and zinc blende; and in a vug or cavity in this stone minerals have crystallised in the following succession—(1) quartz, (2) chalybite, (3) cronstedtite.\*

---

\* On the chemical and crystallographic characters of cronstedtite, see "Mineralogical Notices." By Prof. N. Story-Maskelyne and Dr. Walter Flight. *Journ. Chem. Soc.*, [2] vol. ix. (1871), p. 9.

---

## CASE V.

## DIVISION 1.

## MINERALS OF CORNWALL AND DEVON.

## MINERALS OF THE RARER METALS.

(Nos. 545 to 612.)

The group of specimens exhibited in the first division of Case V. consists of minerals which contain some of the rarer metals of Cornwall and Devon. It is true that the minerals containing silver and antimony, which might fairly take a place here, are exhibited in Case III. by side of the lead-ores, but this is an arrangement due chiefly to convenience of space, though at the same time it is an arrangement which does no violence to the natural relationship of these minerals. On the other hand, manganese, which is conveniently represented in the case now under description, is perhaps hardly entitled to be regarded as a rare metal; yet the ores of manganese are by no means common among Cornish minerals.

An easy transition is effected from the iron-bearing minerals in the last case (No. IV.) to the rarer minerals, now to be described, through the group of nickel and cobalt ores, inasmuch as the two metals which they contain bear very close relationship to iron.

*Nickel and Cobalt Minerals (Nos. 545 to 548).*

The metals nickel and cobalt are found chiefly in the natural condition of arsenides and sulphides, but such minerals are far from common in the West of England. They occur occasionally in the copper- and tin lodes, especially the former, and also in cross-courses, usually near their intersection with the east-and-west veins. Nickel and cobalt are so closely related that they are often associated in the same ore, and the respective minerals are not always readily distinguished from each other by cursory inspection. On weathering, however, the arsenides give rise to arsenates, and are then readily distinguished, since the alteration-product, or "bloom," of the cobalt ore is pink, or peach-blossom tinted, whilst that of the nickel ore presents a peculiar green colour.

*Pentlandite* (No. 545) is an iron-nickel sulphide, or nickeliferous pyrites, which was found at one time in some quantity at Wheal Jane, a lead mine near Truro. *Niccolite* (No. 546), often known by its old German name *Kupfernickel*, is a nickel arsenide, distinguished by its pale coppery red colour. It was formerly raised at the Pengelly Mine, in St. Ewe. *Chloanthite* is an arsenide of nickel with



cobalt, whilst *smaltine*, or *smaltite*, is an arsenide of cobalt with nickel, iron being usually present in both minerals. The specimen of smaltine (No. 547) is from Wheal Sparnon, near Redruth.

Among these cobalt and nickel-bearing minerals the most attractive to the eye is the *Erythrite* (No. 548), which is a hydrated arsenate of cobalt, resulting from the alteration of arsenical cobalt ores, on which it usually appears as an incrustation of a peach-blossom colour, deepening in some specimens into crimson. Crystals belonging to the monoclinic system, are not unknown, but most erythrite is found as an earthy or pulverulent material, often termed *cobalt-bloom*.

### *Manganese Minerals (Nos. 549 to 568).*

Manganese is a metal closely related to iron, and rather widely distributed in nature, though deposits of its ores are not commonly of great magnitude in the West of England. They occur chiefly in lenticular masses and irregular pockets in Devonian and Carboniferous strata, but not usually in persistent veins. At the Restormel Royal Iron Mine, near Lostwithiel, manganese minerals occurred in association with the iron-ores, but only in very subordinate quantity. Most of the ore-bodies containing manganese are found on the north coast of Cornwall and in the eastern part of the county, especially near Launceston; or in the adjacent part of Devonshire, near Tavistock, and again on the eastern side of Dartmoor, north of Exeter. One of the finest deposits was that formerly worked at Upton Pyne, where the ore was first raised about the year 1770. The same vein was also extensively worked at Newton St. Cyres, but the workings at both places were discontinued about 1810 or soon afterwards.\*

Manganese occurs generally in the form of an oxide, which appears to have been deposited from solution, in some cases as a direct precipitate, in others through the intermediate stage of carbonate. The original source of the metal is probably to be sought in the crystalline rocks, where it occurs in many of the constituent minerals, like augite and hornblende, though usually in only small proportion. If the manganese be present as silicate, it may be readily dissolved by water containing carbonic acid, and be then held in solution as bi-carbonate. On exposure to oxidising influences, the neutral carbonate tends to pass into the state of a hydrated oxide. Manganous carbonate is, however, more stable than ferrous carbonate, and consequently in a mixture containing the two carbonates—and they often occur in association—the iron will oxidise first.

It has frequently been observed that in deposits containing ores of both manganese and iron, the manganese diminishes in depth while the iron increases. This is explicable on the assumption that a solution containing carbonates of both metals, rising from

---

\* De la Beche's Report on Cornwall, etc., p. 609.

below, suffered oxidation as it approached the surface. From the experiments of M. Chamussy, of the manganese mines of Romaneche, it appears that from an acid solution of the salts of manganese and iron the effect of a base is to precipitate ferric oxide at first, and that manganese dioxide is not thrown down until long afterwards. Hence the upper part of a deposit of mixed ore is likely to be the richest in manganese.\* Indeed if the oxidising influences are not very powerful, the manganese may remain as carbonate whilst the iron forms a hydrate.

*Manganite and other Oxides (Nos. 549 to 564).*

The characters of *manganite*, or *grey oxide of manganese*, are well illustrated by the specimens Nos. 549 to 562. The mineral is seen in dark steel-grey crystals, belonging to the orthorhombic system, usually in prisms with deep vertical striations. It is a hydrated sesquioxide, related in composition and crystallisation to the corresponding iron-mineral *göthite*.

*Pyrolusite*, or *black oxide of manganese* (Nos. 553 to 556), is a very soft mineral, soiling the fingers, and usually occurring in compact or reniform masses, sometimes with fibrous structure. It is generally a secondary mineral, resulting from the dehydration of *manganite* or from the alteration of the carbonate. When in crystals, which seem generally to be pseudomorphs after *manganite*, the manganese dioxide is termed *polianite*.†

*Psilomelane* is a compact black mineral, never crystallised, but usually occurring in botryoidal masses, like Nos. 557 and 560, or in stalactitic forms, as shown in Nos. 561 to 564. The surface is smooth with sub-metallic lustre, or sometimes velvety. Restormel Royal Iron Mine yielded most of the specimens exhibited here. *Psilomelane* is a hydrated oxide of manganese, of variable composition, frequently impure, and containing barium, etc.

*Manganese Carbonate and Silicate (Nos. 565 to 568).*

*Dialogite*, or native manganous carbonate, is here represented by a Cornish specimen, showing the beautiful rose-red colour which has earned for this species the name of *Rhodochrosite*—a name now frequently employed. The crystalline structure is also well illustrated by this specimen, and from this sparry character it is known as *rose spar* or *manganese spar*. The mineral crystallises in the rhombohedral system, and is isomorphous with *calcite* and *chalybite*. In No. 566 the *dialogite* appears in globular masses of a dark reddish brown colour, with a velvety surface. The colour here may be referred to the presence of iron.

Another manganese mineral of pink or rose-red colour, something like the carbonate but much harder, is the silicate known as

\* "Traité des Gîtes minéraux et métallifères." Par Ed. Fuchs et L. de Launay. Paris, 1893, vol. ii, p. 8.

† See Lacroix's "*Minéralogie de la France*," vol. iii, 1901, pp. 235, 354.



*Rhodonite* (No. 567). The specimen here shown is from Black Down, near Tavistock, in Devonshire. The pink silicate is associated with black oxide, a not infrequent occurrence, since all manganous compounds are prone to pass into a higher state of oxidation, with production of black oxides. In Siberia, the rhodonite is sometimes cut and polished as an ornamental stone, and in this case the black alteration-products contrast strikingly with the original red mineral.

No. 568 is a specimen of *Penwithite*, described by Mr. J. H. Collins as a hydrated silicate of manganese.\* The mineral was found at Wheal Owles, in St. Just-in-Penwith, whence the specific name.

The ores of manganese, chiefly pyrolusite, have considerable economic interest, being used in the production of certain alloys of iron, and in the preparation of bleaching-powder, etc. Pyrolusite is also employed as a source of oxygen, whence its value as a decolourising agent in glass-making.

#### *Bismuth minerals (Nos. 569 to 584).*

Minerals containing bismuth are by no means common in the West of England, but are occasionally found in tin-lodes, and especially in association with ores of cobalt and nickel. Borlase states† that in 1755 it was found by a certain Dr. Schlosser that ores containing bismuth, with cobalt, were being thrown away at a mine in Gwennap, and he consequently devised means for saving and separating them. *Native bismuth* was at one time rather plentiful at Botallack. According to the late Mr. Garby, "masses of some pounds weight have been found in the soil, in the vicinity of Redruth."‡ The metal crystallises in the rhombohedral system, and is often found in crystalline masses, with a platy structure, due to perfect basal cleavage. Lamellar masses of notable size have been found at the Consolidated Mines, St. Ives. The metal presents a tin-white colour, with a suspicion of red, as shown in Nos. 569 to 572. It is extremely fusible, so that miners roughly test an ore for bismuth by observing whether it fuses when placed on a heated shovel.§

Bismuth is one of the small group of brittle metals, including arsenic and antimony, and it is notable that the native bismuth frequently contains traces of both these metals.

Native bismuth is probably a mineral of secondary origin; and it has been suggested by von Fritsch that it may in some cases have been deposited from solutions by electrolytic action.||

\* *Min. Mag.*, vol. ii. (1879), p. 91; vol. iii. (1880), p. 89.

† "The Natural History of Cornwall." By William Borlase, Oxford, 1758, p. 131.

‡ *Trans. R. Geol. Soc. Corn.*, vol. vii. (1865), p. 86.

§ Collins's "Mineralogy of Cornwall," p. 16.

|| "Ueber die Mitwirkung elektrischer Ströme bei der Bildung einiger Mineralien." K. von Fritsche. Dissert. Göttingen, 1862.

The trisulphide of bismuth occurs native, forming the mineral known as *Bismuth glance*, or *bismuthite* or *bismuthinite* (Nos. 573 to 581). Like stibnite, to which it is chemically related, it crystallises in the orthorhombic system, and is usually found in acicular crystals. These needles, well seen in most of the specimens exhibited here, have a tin-white or lead-grey colour, with metallic lustre; but the surface is often obscured by a tarnish, sometimes slightly iridescent. In some specimens, the mineral assumes a filamentous or capillary form, and some beautifully delicate tufts of brown fibres are seen in Nos. 578 and 579. In No. 578 these hair-like crystals are associated with cubes of almost colourless fluor-spar. The association with this spar is also seen in No. 581.

It is probable that the sulphide represents the original form in which the bismuth was introduced into the vein; and the frequent presence of fluorite as a companion suggests that fluorine may have been active at the same time.

*Bismite*, or *bismuth ochre*, is a yellow or brown earthy oxide, resulting from the alteration of native bismuth and bismuth glance, as seen on specimens Nos. 582 to 584.

#### *Pitchblende* (Nos. 585 to 587).

Occurring usually as a black massive substance, without any striking individuality, this mineral was mistaken by the early mineralogists for other substances, such as certain ores of zinc and iron. Its pitch-like appearance and its deceptive characters led to the trivial name of *pitchblende*—a name which still clings to the mineral, even in scientific writings. In 1789 Klaproth showed that pitchblende contained a distinctive metal, previously unrecognised; and as Herschel had just then discovered the planet Uranus, the new metal was rather fancifully named *Uranium*. From the presence of this metal, the pitchblende was called by Haidinger *Uranin*—a word which was modified by J. D. Dana as *uraninite*.

Uraninite, or pitchblende, was formerly regarded as an impure oxide of uranium, and it does indeed contain a large proportion, exceeding in some cases 80 per cent., of  $U_3O_8$ . This may be present as uranous and uranic oxides (respectively containing  $UO_2$  and  $UO_3$ ), whence the mineral was considered at one time to be a proto-peroxide of uranium. It is sometimes described as a uranate of uranyl. Modern research, however, has shown that it is a substance of great complexity, containing lead, bismuth, barium and various rare elements. Most varieties of pitchblende contain thorium or zirconium, and certain metals of the lanthanum and yttrium groups.

The chemical composition of uraninite has been elaborately investigated by Dr. Hillebrand, of the Geological Survey of the United States. In the course of his analysis he obtained, by boiling the mineral with weak sulphuric acid, a gas which was regarded as nitrogen.\* After the discovery of argon by Lord Rayleigh and Sir

\* "On the occurrence of nitrogen in Uraninite." *Bull. U.S. Geolog. Surv.* No. 78, 1889.



W. Ramsay, it was suggested by Prof. Miers that the pitchblende gas should be examined. This examination led Ramsay to the discovery of terrestrial *helium*. He found that the gas evolved from cleveite, a Norwegian variety of pitchblende, when examined spectroscopically, yielded a characteristic line which had been observed in the solar chromosphere by Sir Norman Lockyer as far back as 1868, and referred to a hypothetical element provisionally termed helium.\* The Cornish pitchblende yields only a very small amount of this gaseous body.

Great interest has attached to pitchblende in recent years by reason of its remarkable radio-activity. The property of emitting what are called Becquerel rays was known to be possessed by the metals uranium and thorium, but the investigations of Madame Curie, of Paris, showed that pitchblende was more active than either of these metals. In order to explain this unexpected behaviour she assumed that the mineral must contain some other element of intense radio-activity—an assumption which was confirmed, after a long course of laborious and delicate research, by the discovery of *Radium*.

It is interesting to note that the three elements which have the highest atomic weights are the three radio-active bodies which occur associated, with others, in pitchblende, namely:—

Uranium, atomic weight†	-	-	-	-	-	238.5
Thorium,	„	-	-	-	-	232.5
Radium,	„	-	-	-	-	225

Evidence has been obtained by M. and Mme. Curie, working with M. Bémont, of the existence of another substance of high radio-activity, described as a new 'element' under the name of *polonium*; whilst a third new element has been announced by M. Debierne under the name of *actinium*. In preparing compounds of these bodies from pitchblende, it is found that the radium associates itself with barium, the polonium with bismuth, and the actinium with the rare earths. Yet another substance of great radio-activity has been obtained from pitchblende by M. Marckwald, who has described it as *radio-tellurium*; but it is suggested that this may be a form of polonium.

None of these newly-discovered substances occurs in pitchblende in more than infinitesimal proportion. Of radium, which is the best known and probably the most abundant, it is estimated that only about three grains are contained in a ton of the richest pitchblende.

The occurrence of pitchblende has been recorded from a number of Cornish localities, but it is rarely found in large quantity. Dr. Richard Pearce, in describing its discovery some years ago at Wheal

\* "On a gas showing the spectrum of Helium." By William Ramsay. *Proc. Roy. Soc.*, vol. lviii. (1895), p. 65; also p. 81, and vol. lix., p. 325. "On the new gas obtained from Uraninite." By J. Norman Lockyer, C.B. *Ibid.*, vol. lviii., p. 67; also pp. 113, 116, 192, 193; and vol. lix., p. 342.

† International Atomic Weights (O = 16.) *Journ. Chem. Soc.*, vol. lxxxii. (1902.)

Owles, in St. Just, pointed out that the Cornish pitchblende usually occurs in association with other rare minerals—at St. Austell Consols with nickel- and cobalt- ores; at Dolcoath with native bismuth and arsenical cobalt; at South Tresavean with kupfernickel, native silver and rich argentiferous gozzan. The uranium minerals seem to occur mostly in small cross-veins.\*

In recent years uranium-ores have been successfully worked at Grampound Road, in the parish of St. Stephens, in West Cornwall—at a mine formerly worked for tin, under the name of South Terras. An abundant development of gozzan near the surface yielded a mixture of earthy minerals, variable in composition, containing uranium chiefly in the form of cupro-uranite and calco-uranite. These ores gave way below the 10-fathom level to pitchblende—the mineral from which they had evidently been derived. The pitchblende occurred in a quartz veinstone, associated with much oxide of iron and with occasional bunches of copper ore and argentiferous galena.

According to Mr. B. Kitto the uranium ores occurred in a vein about three feet wide, coursing through killas in a north and south direction. The ores were formerly treated by him, and converted into 'orange' and 'yellow oxide,' most of which was sent to Germany. Uranium compounds are used in porcelain painting, in photography, and in the manufacture of the greenish yellow uranium glass, well known for its fluorescence. It has also been proposed to employ uranium in steel manufacture.

In 1901 the mines at Grampound produced seventy-nine tons of uranium ore, valued at the mine at £2,923.† The mines have since been closed, but will probably be re-opened with the view of supplying material as a source of radium.

The uranium mines have been recently visited by Mr. Clement Reid, in the course of his official work on the Geological Survey. It appears that there are at least two parallel veins, representing cross-courses; and the ore is found to be associated with much magnetite and garnet. Mr. Reid has observed that these veins carry a green garnet, which seems to be *grossularia*—a mineral which it is believed has not been previously recorded from Cornwall.

No. 588 is a specimen of *Zippeite* from Wheal Edward, St. Just. Evidently resulting from the direct or indirect alteration of pitchblende, it appears as a delicate canary-yellow incrustation, with a fibro-scaly structure. With other products of the decomposition of uranium ores, both oxides and sulphates, the zippeite is sometimes known as *uranium-ochre*.

#### *Uranite* (Nos. 589 to 608).

Two minerals have been included under the general name of *Uranite*. Both contain hydrated phosphate of uranium, but in the

\* "Note on Pitchblende in Cornwall." By Richard Pearce. *Trans. Roy. Geol. Soc. Corn.*, vol. ix., p. 103.

† "Mineral Statistics." Home Office Report for 1901 (1902), p. 271.



one case the uranium is associated with copper, in the other with calcium. Hence two species are recognised, known respectively as *Cupro-uranite*, or *copper-uranite*, and *Calco-uranite*, or *lime-uranite*. The former is a green mineral, the latter yellow. Although they seem to agree in the character of their crystallisation, the copper-bearing mineral belongs to the tetragonal system, whilst the lime species is now known to be orthorhombic.

Cornwall is famous for its fine specimens of cupro-uranite, of which many beautiful examples are here exhibited (Nos. 589 to 604). The vivid green colour, the brilliant lustre, the characteristic habit of the crystals and their associations are fully illustrated. The mineral is generally in thin plates, square or octagonal, sometimes curved, and always very fragile; whilst occasionally it appears in rather stout, square, tabular crystals, bearing pyramidal faces at the edges, and exhibiting a perfect basal cleavage. This cleavage is apt to impart a micaceous structure to the mineral, whence it was formerly known as *uranium mica*.

As far back as 1815 the Cornish uranite was examined by William Phillips, who figured a large series of crystals.\* At that time the mineral was regarded as an oxide of uranium.

Many of the fine old Cornish specimens were obtained from the copper-mine of Gunnislake, near Callington, where they occurred in gozzan at as great a depth as 90 fathoms from the surface. Nos. 589 and 590 show the curved platy crystalline masses from this locality, whilst No. 597, also from Gunnislake, shows them spread out in plumose form on a veinstone of quartz with oxide of iron associated with oxide of manganese.

In other specimens, such as Nos. 601 and 602, the crystals are seated on a brown cavernous matrix of gossan. Uranite appears in some cases to be connected with the kaolinisation of felspar; and in Nos. 594 and 595, from near Redruth, the uranium mineral is seen on altered granite, the brilliant emerald-green crystals forming a striking contrast with the dead white matrix. At Stenna Gwynn the mineral is associated with fluellite.

According to Mr. J. H. Collins, uranite is so widely distributed in Cornwall that it occurs "in the shallow parts of almost every copper-mine in the county."† In connection with the self-luminosity of radio-active bodies, it may be worth recalling the observation of the late Mr. Garby that the specimens of uranite "when first discovered by the miners in Huel Buller and Huel Basset were very phosphorescent—so much so that after the lights were extinguished many of the crystals might be discovered *in situ*."‡

The observations of Madame Curie have shown, as might be expected, that both the copper- and the lime-uranites are radio-

\* "On the Oxyd of Uranium, the production of Cornwall, together with a description and series of its Crystalline forms." *Trans. Geol. Soc.*, vol. iii., p. 112.

† *Journ. Roy. Inst. Cornwall*, vol. xii. (1895), p. 52.

‡ *Trans. Roy. Geolog. Soc., Corn.*, vol. vii. (1865), p. 86.

active; and though not so active generally as most pitchblendes they are yet more powerful than metallic uranium.\*

*Torberite*, a name by which cupro-uranite is sometimes known, was given to the mineral by Werner, in honour of the Swedish chemist, Torber Bergmann. As his Christian name was latinised as Torbernus, the mineral name is preferably written *Torbernite*.† *Chalcolite* is another name given to the mineral, but it is apt to be confused with *Chalcocite*, a name frequently applied to copper glance.

The lime-uranite, known also from a French locality as *Autunite*, is less common than the copper-uranite, and usually occurs in yellow or pale yellowish-green crystals, as seen in specimens Nos. 605 to 608. No. 605 shows the intimate association of *torbernite* and *autunite*.

Some of the Cornish *autunite* has been analysed by Prof. Church.‡

It has been suggested by M. Bourgeois that if water charged with sulphuric acid from decomposing pyrites should flow over pitchblende with copper phosphates or with apatite, it might give rise in the former case to *torbernite*, and in the latter to *autunite*—a view supported by the synthetic researches of Debray and Winkler, which show the possibility of the required reactions.§

#### *Churchite* (Nos. 609 to 612).

In 1865 Prof. A. H. Church announced the discovery of cerium for the first time in this country. He found it in a mineral investing quartz and killas, from a Cornish copper lode.|| The mineral proved to be essentially a hydrous phosphate of cerium; and Mr. Greville Williams, who called attention to the presence of didymium, as indicated by means of the spectroscope, suggested that the mineral should be named after its discoverer *Churchite*.¶ No. 612 is interesting as being part of the original specimen analysed by Prof. Church, by whom it was presented to the Museum. The presence of cerium has since been detected by Church in several Cornish apatites.

\* "Radio-active Substances," a Translation of Madame Curie's Thesis. *Chem. News*, vol. lxxxviii. (1903), p. 99.

† "On Mineralogical Nomenclature." By J. D. Dana. *Am. Journ. Sc.* [2], vol. xlv. (1867), p. 147.

‡ "On the Composition of *Autunite*." *Journ. Chem. Soc.* [2], vol. xiii. (1875), p. 109.

§ *Bull. Min. Soc. Fr.*, vol. xxi. (1898), p. 32.

|| "Preliminary Note on a new British Mineral, containing cerium." *Chem. News*, 15th Sept., 1865, p. 121. Also *Journ. Chem. Soc.* [2], vol. iii. (1865), p. 259.

¶ "On the presence of Didymium in *Churchite*." *Chem. News*, 20th Oct., 1865, p. 183.



## DIVISION 2.

## MINERALS OF CORNWALL AND DEVON.

## THE SPARS OF THE MINERAL VEINS.

(Nos. 613 to 690).

All the crystalline minerals which occur in veins, but contain either no metal or only some of the rarer and lighter metals, and which never present a metallic aspect, are conveniently, though rather loosely, grouped together under the popular name of "spars." It is true that the rhombohedral carbonates, which are typical spars, may contain some of the heavy metals and may even be used as ores, so that we speak of the sparry ores of iron, manganese and zinc. But apart from these carbonates, the term is restricted to such minerals as accompany the ores in the form of matrix, gangue, veinstone or lode-stuff, and which are generally regarded as non-metallic or earthy and almost useless.\*

Useless as they may be to the miner, they are of the first importance to the student of mineralogy, inasmuch as they frequently crystallise in forms of much beauty and great scientific interest, whilst their study tends in many cases to throw light on the nature and origin of vein-formations. The principal sparry minerals in the mines of Cornwall and Devon are quartz and fluorspar, with calcite and barytes in subordinate quantity.

In some cases these sparry minerals form small veins, or strings, unaccompanied by any metalliferous mineral, but in most cases they occur in association with more or less ore, the association being often so intimate as to lead to the inference that both matrix and ore must have been introduced into the vein under similar conditions. It is evident that in many cases the mineral matter has been deposited in the cracks of the rocks from a state of solution. Such fissures may be due partly perhaps to the contraction of eruptive rocks on cooling or of sedimentary rocks on consolidation, partly to disruption consequent on the intrusion of igneous matter, or in connection with wider earth movements which have affected large areas of the earth's crust. Mineral veins often run along fault planes.

Whatever the origin of these rock fissures, they would form easy channels through which waters could circulate, bringing with them mineral matter in a state of solution. Solution is usually, though not invariably, facilitated by increase of temperature and of pressure, so that solvents will generally be more effective at great depths than near the surface. A solution, as it travels upwards, along the natural conduit, will be gradually reduced in temperature and relieved of pressure, so that it will become less competent to carry its freight

---

\* Against the use of the word "gangue" see Sir C. Le Neve Foster's remarks in his "Ore and Stone Mining," p. 11. The term "veinstone" is rather ambiguous, since it is employed by some writers to denote the whole contents of the vein, both matrix and ore; whilst others restrict it to the gangue-minerals, or "waste."

of dissolved mineral matter, some of which may consequently be precipitated on the walls of the fissure. The circulating water may have come originally from surface-drainage, and if so will be simply on its return-path, but it is returning charged with more or less mineral matter which it has dissolved during its subterranean sojourn. Solution is more active below, precipitation more active above.

There is not unreasonably a tendency to regard the warm springs, which are sometimes cut in a mine, as surviving representatives of such activities as may have been potent in the deposition of the mineral contents of a vein. It is true that Mr. Henwood remarked that some of the warmest streams he had examined had been from very unproductive lodes. But this obviously does not exclude thermal waters from having been instrumental in depositing the non-metallic veinstuff, or even metallic minerals at former geological periods.

Siliceous deposits containing to a limited extent certain metallic sulphides, and therefore representing true mineral veins, have been observed in course of formation from thermal waters at Steamboat Springs, Nevada; at Sulphur Bank, California; and at Boulder Hot Springs, Montana.\*

The minerals deposited from solution may be either compact or crystalline in texture; and if the solution should stagnate in a subterranean cavity the dissolved matter may very slowly be precipitated, and thus form distinct crystals. Large and fine crystals are generally deposited with extreme slowness. Most of the beautiful crystals exhibited in this collection have been obtained from the walls of fissures, or cavities called vugs in the veinstone, where the conditions must have been exceptionally favourable for crystallisation. A vein-fissure representing a plane of weakness in the rock may have opened again and again; and, offering each time a ready conduit for the circulation of mineral solutions, may have received successive deposits in the course of the history of the lode.

The second division of Case V. is devoted to a fine series of specimens of fluorspar, whilst the other principal spars—quartz, calcite and barytes—are grouped together in the first division of Case VI.

#### *Fluorite (Nos. 613 to 690).*

Since it is believed that the Cornish tinstone has been formed from a tin fluoride, it might reasonably be supposed that fluorspar, the commonest of all natural compounds of fluorine, would be frequently found in tin-lodes. Examples of the association of cassiterite and fluorite are shown in Case I. and have been noticed at p. 26. As a matter of fact, however, the Cornish tin-ore is not so commonly

---

\* See J. Arthur Phillips, *Phil. Mag.*, vol. xxxvi. (1868), p. 321; and "Ore Deposits," 2nd ed., p. 115. The Boulder Springs have been described by Mr. W. H. Weed.



accompanied by fluorite, at any rate macroscopically, as might be assumed. This paucity of fluor, which is a calcium fluoride, may be connected with the general scarcity of calcareous matter in the tin districts of Western Cornwall. In the copper-lodes, however, and yet more notably in the lead-veins, fluorspar is common. This is especially marked in the lead district near Liskeard, where calcite is also a characteristic mineral. Many of the fine specimens of fluorite in this collection are from the lead-lodes of Eastern Cornwall and Western Devon.

The mineral known as *Fluorite*, *fluorspar*, or simply *fluor*, and often termed by Cornish miners *cann*, is a fluoride of calcium, crystallising in the cubic or regular system. Sharply defined cubes, often of large size, are very common: witness such examples as Nos. 613, 618, 622, 678, and 681. A little to the left of this collection stands a Pedestal Case, opposite Wall Case 18, which contains some cubic crystals of fluorite, each measuring more than a foot along the edge. In this specimen, from Wheal Mary Ann at Menheniot, the cubes are of deep blue colour, and certain faces are partially coated with a deposit of pyrites. It is notable that these gigantic cubes are built up of an aggregation of smaller cubes, or sub-individuals.

Octahedral crystals are rare in British fluors. No. 648 shows a combination of the octahedron and cube, whilst No. 668, from Beer Alston in Devon, has the general form of an octahedron, but is a polysynthetic structure made up of aggregated cubes. Yet whatever the external shape of the crystal, fluorite always presents a perfect cleavage parallel to planes of the regular octahedron. The direction of cleavage is so marked in No. 621, that although the cubic crystals maintain their integrity, it is evident that a very slight shock would detach from each three-faced solid angle, or quoin, a tetrahedron which would leave an equilateral triangle representing the face of an octahedron. In like manner the octahedral planes of cleavage are visible in the cracks which run across the translucent quoins of the huge blue cubes in the adjacent case opposite Wall Case 18.

The four-faced cube, known technically as the tetrakis-hexahedron, a kind of cube which seems to carry upon each of its faces a four-sided pyramid, is so characteristic of fluorite that it has been called the *fluoroid*. Sometimes it occurs alone, as in the little violet crystals on No 647, but usually it is found in combination with the cube. Thus, in Nos. 638, 649, 650, 651, not to mention others, the twelve edges of the cube are in each specimen bevelled by the planes of the four-faced cube. Most of these specimens come from St. Agnes, and it is notable that the faces of the tetrakis-hexahedron are, in some cases, rough and corroded whilst the faces of the cube remain brilliant.

It often happens that the faces of a cube of fluor, instead of being quite plane, show markings which represent a very low square pyramid, as may be distinctly seen on No. 621. These facets are known as *vicinal* faces, and possess much significance to the crystallographer.

Another form not infrequently found on crystals of Cornish fluorite is the six-faced octahedron, or hexakis-octahedron. The faces of this form replace the solid angles of the cube, as is clearly shown in the fine specimens of yellow and blue fluor from Wheal Mary Ann, Menheniot, such as Nos. 615, 622, and 623. Thus, in No. 622, which is part of a large cube of blue fluor, the three-faced solid angle is replaced by six planes, which if repeated on all the cube-quoins would constitute the perfect forty-eight-sided form. It will be noted that these corner faces are rough, and this led to the suggestion when such crystals were discovered many years ago, near Liskeard, that the triangular faces might have been artificially filed, but it became evident, on close examination, that the modification was perfectly natural.

Other forms are not common on Cornish fluor, but occasionally the rhombic dodecahedron is represented. On No. 654 the edges of the cube are truncated by rough, rather rounded, inconspicuous planes of this solid. Peculiar interest attaches to this specimen, inasmuch as it shows an internal cube which has been coated with pyrites, upon which more fluor has been deposited, and through this transparent envelope the brilliant brassy pyrite is clearly visible.

Stages in the growth of a crystal may often be detected in fluor-spar, and many of the specimens, such as Nos. 622, 631, 632, and 633, show a zonal structure, due to a regular sequence of deposits. Bands of colour often mark successive episodes in the history of a crystal. Such colour-bands may be detected in many of these specimens; No. 633, for example, is a polished slab which shows, with exceptional distinctness, a number of parallel stripes of vivid green colour. The purple fluors, numbered 631 and 632, are also remarkable for their colour-bands. In Nos. 622 and 623, deep blue zones are well seen in the interior of pale blue cubes.

Fluorite is a mineral which displays great diversity of colour, as seen in the specimens in this Case; but even a greater variety is seen in the Ludlam Collection in the Hall, where Case III. is entirely given up to this polychromatic species. As this series includes foreign specimens, it contains some which possess tints unknown among our British fluors, such, for instance, as the beautiful pink fluor-spar from Switzerland.

Fluor destitute of colour is quite a rarity. No. 616, from Beer Alston, approaches the colourless condition. The dispersive power and refractive power of fluor render the pellucid colourless mineral of value for the construction of objectives for microscopes, as introduced by Prof. Abbe. A variety from Switzerland has been applied to this purpose. The lenses of fluor are used in conjunction with lenses of Jena glass, so as to produce an improved kind of achromatic objective which is termed '*apochromatic*.'†

---

\* See Prof. Miers's "Mineralogy," 1902, p. 96.

† "Jena Glass." By Dr. H. Hovestadt. Translated and edited by J. D. Everett, M.A., F.R.S., and Alice Everett, M.A. 1902. P. 88.



Many of the specimens exhibited in this Case show that the faces of crystals of fluor-spar are apt to be corroded and etched to a remarkable extent. Nos. 616, 618, 620, and 656, not to cite other instances, clearly show the etched figures due to the action of natural solvents. In some of the specimens from Beer Alston the edges and solid angles have been so roughened and rounded that the cubes show a tendency to become rather spherical, as seen in Nos. 660, 661. From the old mines of Beer Alston, between Tavistock and Plymouth, where argentiferous galena was formerly worked on an extensive scale, a fine suite of crystallized fluors is here exhibited, including certain specimens of rich smalt-blue colour, and others of pale sea-green tints, such as Nos. 657 to 668. It is notable that while the lead mines of South Devon have yielded such fine specimens of fluor, the old mines of silver-lead in North Devon, like Combe Martin, were not remarkable for this mineral.

Some of the boldest crystals of fluorite shown in this case were obtained from the lead mines formerly worked at Menheniot near Liskeard, especially from Wheal Mary Ann. Many of these show characteristic associations of minerals. Thus in No. 653 the fine yellow cubes, implanted on crystalline quartz, are sprinkled over with brilliant cubo-octahedra of pyrite. No. 669 is an instructive specimen, showing large octahedra of pale green fluor coated with minutely crystallized quartz, giving a white drusy surface to the crystals, and on this surface there has been formed a second deposit of fluor, this time in purple crystals, showing a combination of cube and four-faced cube, and finally on this purple fluor copper-pyrites has crystallized.

In No. 674, from near Redruth, a base of copper-pyrites having a tarnished surface, due probably to a coating of covellite, carries prismatic crystals of dead white quartz, associated with fluorite in pale yellowish green cubes, having the quoins modified by planes of the six-faced octahedron and the interior zoned with blue bands. In No. 675, from Caradon, a matrix of green fluor is partly hidden beneath a crop of snow white crystals of quartz, on which occurs a second growth of green fluorite, bearing a final crystallization of copper-pyrites.

Calcite is associated with several of the specimens of fluorite from Menheniot. Thus, the blue cubes of fluor in No. 670 are moulded on crystals of quartz, but carry on their surface calcite in white crystals, consisting of obtuse rhombohedra combined with the hexagonal prism. In No. 681, again, fine cubes of blue fluor are encrusted on certain faces with quartz in small crystals, producing a drusy surface, and on this quartz calcite has finally crystallized.

It is notable that fluorite is often *pyrophosphoric*, that is to say, it becomes self-luminous on exposure to very moderate heat. The amorphous opaque white fluor, No. 686, is remarkable for its phosphorescence. When slightly heated it emits a beautiful green glow, whence the name *Chlorophane* sometimes applied to such a variety of fluor—whence also the term *pyro-emerald*. Since this white fluor

exhibits a green light, the colour of the phosphorescent glow seems to bear no necessary relation to the colour of the mineral.

Pseudomorphs after fluorite are well known to collectors. In Nos. 687 and 688 cubes of fluor are encrusted with a deposit of quartz, giving the crystals a drusy surface. In No. 689 the fluor has been removed by solution, leaving a cubic hollow, in which a little chalybite has crystallized. Other epimorphs, showing cube-shaped cavities, left probably by the removal of fluor-spar, are exhibited in Case IV. (*see* No. 515, p. 69).

In No. 690 from Tavistock, octahedra of pale green fluorite are superficially replaced by opaque white chalcedonic silica, or hornstone. In Case VI., the specimen No. 774 shows a fine octahedron, consisting of chalcedony which has entirely taken the place of fluorite.

The ultimate source of much of the fluorite in the Cornish lodes is probably to be traced back to a very early phase in the history of the veins. Some of the fluor may indeed have been connected with the original formation of the tinstone. If it be admitted that the cassiterite has been formed by the reaction of tin-fluoride and water-vapour, it is evident that the formation of the stannic oxide would be accompanied by the production of hydrofluoric acid. This acid acting on lime-bearing minerals, such as certain felspathic constituents of the granite, might produce calcium fluoride. Hence the formation of cassiterite would be accompanied or followed by the production of fluor-spar.

It is known that fluorine, in the form of hydrofluoric acid and fluoride of silicon, occurs among the exhalations from fumaroles, whilst calcium fluoride and other solid substances containing fluorine are found among volcanic sublimates. There is no reason to doubt, however, that most of the fluorite from the mines of Cornwall and Devon has been formed by deposition from solution, probably in thermal waters. Fluorine is known to occur in certain natural waters, notably in some of the hot springs of Galicia. Whilst it is present in some waters as sodium fluoride, it exists in others as calcium fluoride. Small crystals of fluor have been found on mortar in the old Roman baths of Plombières; but here it was probably derived from the fluorite which existed in the granite through which the water passed. Glasses used at thermal springs often acquire a dull surface, but the popular notion that this is due to corrosion by hydrofluoric acid is not always correct.



## CASE VI.

## DIVISION 1.

## MINERALS OF CORNWALL AND DEVON.

## THE SPARS OF THE MINERAL VEINS, CONTINUED.

*Quartz* (Nos. 691 to 718).

Of all the minerals which contribute to the formation of the vein-stones in the West of England, *Quartz* is by far the most abundant.\* As it is so much harder than the other sparry minerals of the veins—fluorite, calcite and barytes all yielding readily to the knife whilst quartz resists—it is sometimes termed by the miners ‘*hard spar*’; or it is referred to, in consequence of its abundance, as simply ‘*spar*.’ Some of its general characters have already been noticed (p. 21).

Where cavities, or vugs, occur in the veinstone, the quartz will have opportunity for free crystallisation, and the walls of these hollows may consequently be lined with crystals. In like manner, the sides of fissures in granitic or slaty rocks, may be studded with crystals of quartz. It is from such situations that the fine specimens here exhibited have been derived.

A crystal of quartz, when developed under favourable conditions, usually assumes the form of a six-sided prism, attached by its base to the veinstone or to the mother-rock, and terminated at the free end by a six-sided pyramid. Most of the crystals in this case exhibit such a combination of forms. In many of the specimens the prisms are elongated along the vertical axis, producing slender crystals, whilst in others the planes of the terminal pyramid predominate, giving rise to groups of short sharp-pointed crystals: Nos. 695 and 696 illustrate the former, and No. 691 the latter habit. In the quartz-porphyry of many Cornishelvans bi-pyramids of quartz are not uncommon. In No. 693 the crystal of quartz appears to be flattened by the development of two opposite faces of the prisms at the expense of the others. The planes of the terminal pyramid may be equally developed, producing regular forms like those of No. 670; but it frequently happens that the pyramidal planes are alternately large and small, as seen in No. 696, thus suggesting that the faces are really those of two correlative rhombohedra.

It is very characteristic of quartz that the prism faces are striated transversely, that is, in a direction perpendicular to the morphological axis, as seen with great distinctness in Nos. 694 and 696. This is due to an oscillatory combination of the prism and a pyramid.

\* Quartz is probably the most widely distributed mineral in Nature “next to water.” (Max Bauer’s *Lehrbuch der Mineralogie*, Stuttgart: 1904.)

Most of the crystals of quartz in the series, numbered 691 to 698, are more or less opaque, in some cases snow-white or dead-white. This character is common in crystals of quartz from veinstones, whereas quartz which crystallises in the fissures of granite and slate is often transparent, and sometimes quite pellucid. When clear and colourless quartz is known as *Rock crystal*, and crystals of this kind may be found in nests along the joints of slaty rocks in the cliffs at Tintagel and in the Delabole quarries. Small crystals are usually more perfect in shape and brilliant in lustre than large ones. The limpid colourless crystals are known as *Cornish diamonds*.

In describing the old museum of the Royal Society, Grew wrote : "Of our bastard diamonds here in England the Cornish are the best."\* Borlase, in his "History," describes and figures a number of Cornish crystals of quartz, referring especially to a very fine collection made by Mrs. Grace Percival, and preserved "in her Fossilary" at Pendarves for the "attentive inspection of every inquisitive Fossilist."†

Quartz sometimes assumes a brown colour, more or less pronounced, and is then termed *Smoky quartz*. No. 707 is a beautifully sharp and clear crystal, from Tintagel, with a faint brown tinge. The colour of smoky quartz is often referred to the presence of organic matter, but in some cases it is said by Weinschenk to be due to the presence of a compound of titanium. This crystal encloses delicate hair-brown needles, probably of rutile, or titanium dioxide.

In the fine example of *capped quartz*, No. 700, a hexagonal pyramid of the mineral fits perfectly into a hollow envelope, which has formed its cap. Between the formation of the crystal and the cap, a thin coating of some foreign substance, like mica in some specimens or clay in others, has been deposited, so as to interrupt the continuity of growth and secure freedom between the original formation and its shell.

No. 701 shows a curious form of yellowish quartz in globular masses composed of diverging columnar crystals, which give rise, on fracture, to a stellate appearance. Since fibrous quartz is occasionally found in the cross-courses in Cornwall, it is known to the miners as *cross-course spar*.

The so-called *hacked quartz*, represented by No. 703, is crystalline quartz with apparent incisions, as though the mineral had been cut. These hollows have been left by the disappearance of thin tabular crystals, probably barytes, between which the quartz had been deposited. In No. 704 from Herodsfoot Mine the crystallised quartz forms an *epimorph*, having invested tabular barytes, which on removal would leave imprints like those of hacked quartz.

The well-known *Babel quartz* is illustrated by No. 705, from Beer-alston in Devonshire. Here the white crystalline quartz has been

---

\* "Museum Regalis Societatis," London : 1681, p. 283.

† "The Natural History of Cornwall," Oxford : 1758, p. 122.



developed in little step-faced turrets, rising from a broadly extended face of quartz, which seems to have been itself deposited on crystals of fluor-spar, now vanished.

*Amethyst*, more or less pronounced in colour, is occasionally found in the mineral-veins of Cornwall, and notable specimens have been obtained from Wheal Uny and Wheal Tolgus, near Redruth. In No. 708 the violet tint is pale, whilst in No. 709 it is a rich deep colour, and in No. 710 the pigment seems so dense as to render the crystal practically black. The colour of amethyst is commonly referred to the presence of manganese, in the state of oxide. It is notable that on exposure to a moderate heat the amethystine colour is lost, and the mineral becomes greenish yellow, like the variety of quartz known as *Citrine*. Much of the yellow quartz used as an ornamental stone is simply "burnt amethyst." Veins of amethystine quartz lose their colour at the outcrop, becoming first greenish and then colourless. Sulphur has been detected in certain kinds of amethyst, and the colouring agent has been regarded by A. Nabl as ferric thiocyanate.\*

Professor Judd has shown that amethyst usually exhibits a lamellar structure, due to mechanical stresses, and has suggested that quartz which has a tendency to undergo this molecular change should be distinguished as *unstable quartz*.† Such quartz presents, on fracture, a rippled surface; and all quartz which displays this structure, whatever its colour, is sometimes termed, following Brewster, amethyst. The intersection of two systems of curved ripples or 'thumb-marks,' may produce on the fractured face a pattern not unlike that resulting from 'engine turning.' The unstable quartz has a great tendency to assume purple colours, and, moreover, the colour is often concentrated along the lines between the lamellæ. The optical properties of amethyst have been the subject of much study; and it is notable that the component lamellæ in the mineral are alternately right-handed and left-handed with regard to their action on polarised light.

Red quartz, known frequently as *Eisenkiesel*, owes its colour in most cases to mechanically enclosed oxide of iron. Such *iron quartz* is well illustrated by the series Nos. 711 to 714, from the Restormel Royal Iron Mine, near Lostwithiel. In No. 713 the rich red quartz is associated with psilomelane, or oxide of manganese. Quartz crystals not infrequently enclose foreign substances, such as the specular iron-ore in No. 694.

The interesting specimen No. 715, from Cook's Kitchen, near Camborne, shows large crystals of quartz bearing hollow epimorphs, which are thin crusts that have taken the form of lenticular crystals of chalybite and are themselves sprinkled over with red oxide of iron.

\* *Journ. Chem. Soc.*, 1899 (Abstracts), p. 561.

† "On the Development of a Lamellar Structure in Quartz-crystals by mechanical means." By Prof. John W. Judd, F.R.S. *Min. Mag.*, vol. viii. (1889), p. 1. Also: "Additional Notes." *Ibid.* vol. x. (1894), p. 123.

No. 716, from Botallack, is a specimen of quartz pseudomorphous after calcite in obtuse rhombohedra.

Many interesting associations of quartz will be observed in this series. Some very fine bisphenoids of copper-pyrites are crystallised on the group of prismatic crystals of quartz in No. 696, from Redruth, whence also was obtained the next specimen (697) which shows a somewhat similar grouping of quartz and chalcopyrite. Excellent crystals of mispickel have seated themselves on the quartz in No. 695.

The history recorded by the specimen, No. 698 is as follows : opaque white quartz has crystallised on a chloritic veinstone, with copper pyrites ; then chalcopyrite in bisphenoids, now tarnished, has been formed on the quartz ; and finally, chalybite has been developed, in aggregates of fish-scale crystals. In No. 691 sea-green fluorspar has crystallised in bold cubes on quartz in fine hexagonal prisms, with pyramidal terminations ; and then a secondary growth of quartz has taken place, this time in small crystals beautifully pellucid, and doubly terminated. In many other specimens it will be noticed that a second crop of quartz crystals, often of small size, has been formed on large pre-existing crystals of quartz.

*Calcite (Nos. 719 to 742).*

Carbonate of lime is rare in the veinstones of Cornwall, and is practically absent where the veins run through granite. In eastern Cornwall there is more calcareous matter than in the west, and Mr. Collins has suggested that this "perhaps points to a former westward extension of overlying Devonian limestones."\* In the tin lodes of the west, carbonate of lime is quite an exceptional mineral. The specimen, No. 38 (Case I.), is interesting as showing wood-tin with the laminated variety of calcite known as Schiefer spar or "slate spar." Most of the specimens in this Case have been obtained from the lead mines near Liskeard, especially from Herodsfoot and Wheal Wrey.

*Calcite*, or native carbonate of lime, crystallises in the hexagonal system, and presents perfect cleavage parallel to the fundamental rhombohedron. Greg and Lettsom remark that "in Cornwall and Devonshire low hexagonal prisms and tabular forms prevail."† This assertion is partly justified by No. 739 from Botallack, and No. 740 from Wheal Friendship, near Tavistock—the crystals in both specimens having a tabular habit by predominance of the basal pinacoid and only slight development of the hexagonal prism.

The beautiful white crystals from Wheal Wrey, associated in some cases with iron pyrites in brilliant cubes, are either slender prismatic crystals like those in Nos. 720 to 722, or stout prisms as in No. 724.

Careful examination will show that what looks like a hexagonal prism is often a very acute rhombohedron, the faces not being

\* *Journ. Roy. Inst. Corn.*, vol. xii. (1894), p. 54.

† "Manual of the Mineralogy of Great Britain, etc.," p. 36.



parallel-sided. Two generations of calcite crystals may be noted in some of the specimens, as in No. 723, where the larger crystals are apparently impaled by the slender prisms, to which they are therefore subsequent. In Nos. 728, 729 the calcite appears in sheaf-like aggregates of crystals, on a base of red quartz with a thin coating of secondary quartz and a sprinkling of pyrite. The beautiful snow-white calcite of Herodsfoot (No. 732) in polysynthetic crystals is likewise associated with quartz and pyrites.

In No. 741 the calcite is pink, in consequence of a little associated iron or manganese.

Calcite, by reason of its ready solubility in carbonated waters, is a mineral of great mobility, being easily removed from one situation and deposited in another. Waters containing sulphuric acid from decomposed mundic will remove the lime as sulphate, and tend to deposit it as gypsum. No. 742 is a specimen of finely crystallised selenite from a gypseous deposit in a boiler near Redruth, which was fed with water containing sulphate of lime in solution.

#### *Dolomite (Nos. 743 to 746).*

Calcite is subject to some variability in chemical composition by the replacement of its calcium to a greater or less extent by other divalent metals, notably by magnesium. When a considerable proportion of magnesium is present, the spar frequently displays a pearly lustre on the faces of the crystal, whence it is known as *pearl spar*. If the two carbonates be present in equal molecular proportion, the resulting compound is the double carbonate termed *Dolomite*. In specimen No. 743 the spar exhibits not only the nacreous lustre but the characteristic curvature of the faces, the curvature becoming so pronounced as to produce "saddle-shaped" crystals. Here the dolomite is seated on quartz, well crystallised and slightly amethystine in tint, and is itself sparsely sprinkled with pyrites.

No. 744, from Menheniot, shows the following sequence of deposits viz. : (1) quartz; (2) fluorite; (3) second growth of quartz; (4) dolomite; (5) pyrite. The fluor is in blue cubes; the quartz of the second generation is in very small clear sharp crystals; and the opaque white dolomite is in rhombohedra, which have their faces slightly curved and distinctly pearly, as seen also in Nos. 743 and 745.

In No. 745, from Beer Alston, in Devon, the succession is simpler, being (1) fluorite, (2) chalybite, and (3) dolomite. No. 746 is noteworthy for its well-formed rhombohedra, different from the lenticular crystals on some of the previous specimens.

Dolomite has been formed artificially in various ways: for example, by heating carbonate of lime with a magnesian solution, such as the bicarbonate or the chloride. Even at 100° C. dolomite may be so formed, but a higher temperature favours the reaction.\* Dolomite

---

\* F. Hoppe-Seyler in *Zeitsch. f. Geol.*, vol. xxvii. (1875), p. 495.

has also been detected as a natural precipitate from certain mineral waters.\* The subject will be again referred to.

*Barytes* (Nos. 747 to 758.)

Although *Barytes*, or sulphate of barium, is a very common mineral in the vein-stones of the north of England, it is remarkably rare in Cornwall, even in the lead-lodes. Formerly one of the chief localities for Cornish barytes was the mine in Gwennap called Ale and Cakes, afterwards one of the "United Mines," and subsequently absorbed in the Consolidated Group. Here the mineral occurred in a copper lode, at a depth, according to Mr. Garby, of 170 fathoms from the surface.† Nos. 755 to 757, from this locality, show the characteristic greenish grey colour of the crystals, and their aggregation in sheaf-like groups. The crystals tend to become darker in colour on long exposure to light.‡

Some of the silver-lead mines in the neighbourhood of Liskeard have yielded beautiful specimens of barytes in sharply defined crystals of yellow colour, brilliant lustre, and tabular habit; witness the specimens Nos. 747 to 754, from Wheal Mary Ann, in Menheniot. Iron-pyrites occurs here in association with the barytes; and its decomposition may have furnished sulphuric acid to the waters of the mine, so that on meeting a solution containing any barium salt, the almost insoluble sulphate would be precipitated.

In No. 753 the following succession of minerals is shown: (1) fluor-spar in sea-green cubes; (2) quartz in white prisms; (3) barytes in pale brown tabular crystals. The pink barytes, No. 758, is from Babbicombe in Devon, where it occurs in the limestone.

Further remarks concerning barytes may be conveniently deferred until the more typical examples from other localities come under review (pp. 168, 186).

## DIVISION 2.

### MINERALS OF CORNWALL AND DEVON.

#### MISCELLANEOUS MINERALS.

(Nos. 759 to 826).

A number of Cornish and Devon minerals which could not, with regard to scientific propriety, be placed in any of the foregoing classes are here grouped together as a miscellaneous assemblage, brought into association only by their local occurrence. They form a group with no pretence to homogeneity, either chemical or geological, including as they do such diverse minerals from such varied formations as—wavellite from the Carboniferous shales, calcite from the Devonian limestone, various silicates from the altered

\* Comptes Rendus, vol. c. (1888), p. 665.

† Trans. Roy. Geol. Soc. Corn., vol. vii. (1865), p. 81.

‡ J. H. Collins; "Handbook," p. 13.



killas, felspars from the granite, and garnets and other minerals from the greenstones, with a few other substances obtained from certain lodes but hardly suitable for exhibition in any of the preceding series. Although these minerals could not be appropriately placed elsewhere, it seems necessary to exhibit them in order to bring the collection within some reasonable approach to completeness as representative of the mineral resources of Cornwall and Devon.

*Chalcedony (Nos. 759 to 776).*

Silica occasionally occurs in veins in the condition of *Chalcedony*, but although this is chemically identical with quartz it could hardly be placed by the side of that mineral, in the group of spars, inasmuch as it is not apparently crystalline, and crystalline structure is an essential characteristic of a "spar." Instead of forming crystals, chalcedony usually occurs in masses which are mammillary, botryoidal, or stalactitic in form. Yet, when examined in thin sections under the microscope, the chalcedony is seen to possess a crystalline structure, being composed of fibres, which differ however in optical characters from true quartz. Hence chalcedony is regarded as a *crypto-crystalline* or *micro-crystalline* variety of native silica.

Very beautiful examples of stalactitic chalcedony were formerly obtained from the Trevascus mine, in the parish of Gwinear, and some are here exhibited which show admirably the delicate and even fanciful shapes of the specimens from this locality (*see* notably Nos. 759, 760, 763, 770). Many other examples of rather similar character are shown from Pednandrea, near Redruth (Nos. 767 and 768). These specimens sufficiently illustrate the characteristics of the mineral—its grey yellow or brown tints, its translucency, its rather waxy or resinous lustre, and its conchoidal fracture. It is notable that the surface is coated in some cases with a bluish bloom, of much delicacy and beauty, as seen on Nos. 765 and 766. Other specimens of chalcedony, perhaps still finer, are exhibited in the Ludlam collection in the Hall, Case IV.

The forms of chalcedony at once suggest that it has been deposited from siliceous solutions; and it was formerly supposed that a little opal, or soluble hydrated silica, was often associated with the fibro-crystalline mineral, thus causing the chalcedony to have a slightly lower density than that of quartz. In No. 772 a chalcedonic substance, scarcely, if at all, distinguishable from true flint, from the Chalk, has been deposited in a brecciated copper-lode, with chalcopryrite, siderite and 'peach.'

Chalcedony sometimes forms a coating over crystals of quartz and other minerals, as shown in Nos. 761 and 762. On the removal of the invested mineral, the chalcedonic crust may be left as a hollow shell, such as is seen in No. 773. Here the angular cavities in the chalcedony represent the shape of the mineral removed, apparently in this case fluorspar. True pseudomorphs of chalcedony are not uncommon, and in No. 774 the mineral has assumed the form of a

fine octahedral crystal of fluor. The material of such pseudomorphs is often described as *hornstone*. In some cases the fluor is simply invested, but in others completely replaced, by the chalcedonic mineral.

The remarkable pseudomorphs known as *Haytorite* (No. 775) are composed of chalcedonic silica which has taken the form of datolite. According to Geinitz, who examined the material microscopically, the pseudomorphism was effected by gradual change and not by envelopment. Datolite is a basic silicate of boron and calcium, sometimes regarded as a boro-silicate of lime. Dr. Busz has detected datolite with garnets, in the limestone of South Brent in Devonshire\*; but though now extremely rare as a British mineral it must have existed in large crystals when these fine pseudomorphs were formed. Haytorite takes its name from the locality on Dartmoor, where it was discovered. The Haytor iron mine yielded not only haytorite, but also pseudomorphs of chalcedony after calcite. The magnetic iron ore of this mine has already been referred to (p. 66). Haytorite has likewise been recorded from North Roskear Mine, in Cornwall.

*Beekite* (No. 776) is an orbicular form of chalcedony, named after Dr. Beek, Dean of Bristol, who first called attention to it, as an incrustation on fossils in South Devon. It was described by the late Mr. W. Pengelly† and analysed by Professor Church.‡ Beekite generally appears either as a deposit of silica in concentric annular masses on corals and other fossils, or as a pseudomorphic replacement of them, but it occurs also on fragments of limestone which are not distinctly organic. Prof. T. McK. Hughes regards the beekite as chalcedonic chert formed as a thin layer just beneath the surface of the limestone, and revealed only on removal of the external crust: the siliceous material then exposed may form a hollow shell so thin as to float on water, and in some cases enclosing loose earthy matter which rattles when shaken.§

Certain siliceous minerals more or less akin to chalcedony, but differing generally in optical characters, have been discriminated by the microscopic investigations of French mineralogists in recent years, and have received distinctive names, such as lussatite, lute-cite, quartzine and pseudo-chalcedonite.||

*Opal*, or hydrated silica deposited in a colloidal state as an amorphous mineral, less hard and less dense than quartz, is by no means common in the West of England. No. 777 is an interesting specimen showing opal in association with cassiterite. This specimen from Trumpet Consols, near Helston, was presented by the late Sir W. W. Smyth, F.R.S., and shows the opal as a milk-white and pale blue translucent mineral.

\* *Geol. Mag.*, 1896, p. 492. *N. Jahrb f. Min.*, 1899, p. 90.

† "On the Beekites found in the Red Conglomerates of Torbay." *Rep. Brit. Assoc.*, 1856, p. 74.

‡ *Phil. Mag.* [iv.], vol. xxiii., p. 95.

§ "On the manner of occurrence of Beekite and its bearing upon the origin of siliceous beds of Palæozoic age." *Min. Mag.*, vol. viii. (1889), p. 266.

|| See Prof. Lacroix, "*Minéralogie de la France*," vol. iii. (1901), p. 120.



In connection with the formation of opal, chalcedony and quartz in mineral-veins, it may not be out of place to call attention to an observation of Prof. Spezia, during the construction of the Simplon tunnel through the Alps. He obtained, from a fissure in the gneiss, a gelatinous substance, like vaseline, apparently a mechanical mixture of silicic acid and aluminium hydroxide, in a colloidal condition. Very minute crystals of quartz were embedded in the substance, and it is suggested that this gelatinous silicic acid probably represents a stage in the formation of quartz.\*

*Calcite* (Nos. 778 to 783).

The specimens of *Calcite* here grouped together could hardly find a place with the calcites already described from the lodes of Cornwall and Devon, inasmuch as they were obtained not from mineral-veins, but from limestone quarries. With the exception of No. 782, which is a specimen from Ashburton, all the calcites here exhibited are from the quarries near Plymouth, opened up a century ago to furnish stone for the construction of the breakwater.

The Plymouth rag forms part of the Great Devon Limestone, which is referable to the Middle Devonian, or Eifelian, group of strata. Between 3,000,000 and 4,000,000 tons of limestone were extracted for Rennie's great structure from quarries at Oreston, about a mile from Plymouth. In the fissures of the rock, as is common in other limestones, crystals of calcite were found. Some of the specimens, as Nos. 778 and 779, show the crystals attached to the mother-rock; whilst others, like Nos. 780 and 781, exhibit the crystals clustered around stalactites which have formed in cavities of the limestone. Some of the specimens, notably Nos. 780 and 781, possess a yellow colour, which has often suggested to quarrymen the name of *sugar candy spar*. The colour is no doubt referable to a trace of iron, much of the Devonian limestone being veined and clouded with ferruginous stains.

In No. 783, from the Ilfracombe limestone, the carbonate of lime has been deposited in a coralloidal form, and appears to be in the condition of *Aragonite*. This species, though chemically identical with calcite, is slightly denser and harder, and when crystallised assumes forms of the orthorhombic system. (See p. 150.)

*Wavellite, etc.* (Nos. 784 to 790).

According to the late Mr. Townshend Hall, *Wavellite* was discovered about the year 1785 by Mr. I. Hill, of Tavistock.† Sir Humphry Davy, who examined it chemically in 1805, says, "This fossil was found many years ago by Dr. Wavel in a quarry near Barnstaple."‡

\* *Journ. Chem. Soc.*, vol. ii., 1901 (Abstracts), p. 393.

† "On the Mineral Localities of Devonshire." *Trans. Devon. Assoc.*, vol. ii., Part ii., 1868, p. 332.

‡ "An Account of Some Analytical Experiments on a Mineral Production from Devonshire." *Phil. Trans.* for 1805, p. 155.

It was taken at first for a zeolite, but Davy was led to regard it as a hydrate of alumina and proposed to call it, from this false notion of its composition, *hydrargyllite*, though he states that Dr. Babington had suggested that it should be named *wavellite* after Dr. Wavel, of Barnstaple. The true nature of the mineral as a hydrated phosphate of alumina was determined by Wavel.

Wavellite occurs in black slaty rocks of the Culm-measures at Filleigh, between Barnstaple and South Moulton, in North Devon. As seen in Nos. 784 to 788, it forms small hemispherical masses, composed of radiating fibres of acicular crystals, of white, grey, brown, or bluish colour; whilst in the narrow crevices of the rock it spreads out in the form of circular films, with a radiate structure. With these typical specimens from Devonshire, the visitor may compare the Irish wavellite, represented in Case XII. The species has also been found in Gower, in South Wales, by Mr. R. H. Tidde-man.\*

*Tavistockite*—a rare mineral from near Tavistock, described by Prof. A. H. Church,† and represented by Nos. 791 to 793—appears to be a hydrated phosphate of aluminium and calcium. The specimens show its occurrence on quartz, with copper-pyrites in one case, and with fluor spar in another.

#### *Felspars, etc. (Nos. 795 to 800).*

In the fissures or drusy cavities of granitic rocks, the component minerals—notably the felspar—may occasionally be found in well-developed crystals. The specimen No. 795, from St. Austell, shows crystals of opaque white *Orthoclase*, or potash-felspar, associated with pale sea-green apatite, and the yellowish-green micaceous mineral called *gilbertite*. Minute cubes of pyrite are scattered sparsely over the felspar.

In the tray numbered 797 are two large, thin tabular crystals of orthoclase, showing the composite twin forms known as “Carlsbad twins.” Such crystals have the broad planes of the clinopinacoid well developed, and are said to present the “sanidine habit,” since the variety of orthoclase called *sanidine* is typically tabular. The crystals here exhibited come from Caudle Down, St. Austell, and have suffered partial kaolinisation, so that they present a dead white appearance, with a rough, dull surface. Some of the porphyritic granites of Cornwall exhibit very large crystals of white orthoclase, with a beautiful zonal structure marked by inclusions, as may be seen in several of the polished columns and other ornamental objects in the Hall. The alteration of felspar with production of kaolin, or china-clay, has already been referred to (p. 10).

The polished specimen, No. 798, from the Triassic conglomerate of Heavitree, near Exeter, displays the flesh-red crystals of a variety

\* Summary of Progress, *Geol. Surv. for 1901 (1902)*, p. 42.

† *Journ. Chem. Soc.* [2], vol. iii. (1865), p. 263.



of orthoclase, which was named by Lévy, in 1827, after Sir Roderick I. Murchison (*b.* 1792, *d.* 1871).\* *Murchisonite* is notable for the peculiar sheen, or *schiller*, which it exhibits on one of its cleavage-planes. The mineral may possibly be an altered felspar from the granite of Dartmoor.

Crystals of *Albite*, or soda felspar (No. 799) are sometimes found studding the walls of fissures in the Devonian slaty rocks of North Cornwall. Excellent crystals occur, in association with quartz and calcite, in the joints of the slates at Tintagel. The minerals of this locality have been well described by Mr. H. L. Bowman.†

On the albite of Lanterdan Quarry, Prof. Miers discovered *Monazite* ‡—a phosphate of the rare cerium metals, which in recent years has been used in the preparation of mantles for incandescent gas-lights. Monazite is usually associated with titanium minerals, and it is therefore not surprising to find that needles of *rutile* are found with it on the Tintagel albite, whilst *anatase* occurs in the immediate neighbourhood.

In the tray No. 800 are two specimens of *Pinite* in a schorlaceous elvan from St. Hilary, in West Cornwall. Pinite is a mineral not infrequent in the granites and elvans of the Land's End district; and here, as elsewhere, it seems to be an alteration-product of cordierite.§ The cordierite is a silicate of aluminium and magnesium, with more or less iron, which readily suffers transformation into micaceous and other substances. In pinite, which is sometimes regarded as an impure massive variety of muscovite, the form of the original cordierite is faithfully retained, so that the mineral seen in these specimens may be regarded as a true pseudomorph. Mr. J. H. Collins has suggested that the Cornish pinite may in some cases be pseudomorphous after nepheline.¶

#### *Garnets, etc. (Nos. 801 to 808).*

Garnet is hardly to be regarded as an uncommon mineral in Cornwall, though good crystals are not of frequent occurrence. Some of the best occur in the cliffs in the neighbourhood of Botalack, in West Cornwall, whence the examples here shown as Nos. 801 to 802 have been obtained. These rather resemble the iron-alumina garnets known as *almandine*. They present a deep red colour—so deep as to appear almost black in the stout crystals, but showing colour and translucency towards the edges. In form they are well-developed icositetrahedra—or solids bounded by twenty-four

\* "On a New Mineral Substance proposed to be called Murchisonite." *Phil. Mag.*, vol. i. (1827), p. 448.

† "On Monazite and Associated Minerals from Tintagel, Cornwall," *Min. Mag.*, vol. xii. (1900), p. 358.

‡ "On Monazite from Cornwall," *Min. Mag.*, vol. vi., 1886, p. 64.

§ For the nature and formation of this mineral the following paper should be consulted: "The Natural History of Cordierite and its Associates." By J. J. H. Teall, M.A., F.R.S., *Proc. Geol. Assoc.*, vol. xvi., 1900, p. 61.

¶ "On the Pinite of Breage in Cornwall," *Min. Mag.*, vol. x. (1894), p. 8.

trapeziums. These crystals are embedded in a dark amphibolite, or hornblende-schist, from which they are readily detached, leaving very sharp impressions in the matrix.

Common garnet is now generally known as *andradite*, including the varieties sometimes regarded as allochroite and colophonite. No. 805, from St. Just, shows garnet of orange-brown colour, crystallised not very distinctly in rhombic dodecahedra, having the edges truncated by planes of the icositetrahedron, and associated with axinite. Somewhat similar garnet from Okehampton, in Devon, is seen in No. 803.

In the specimen No. 804, from the old Belston Mine, near Okehampton, garnet is associated not only with axinite but also with copper-pyrites and mispickel. This unusual association, which was described by Sir W. W. Smyth, occurred in the metamorphic zone at the margin of the Dartmoor granite, where considerable workings for copper-ore were at one time carried on.\* A similar specimen is in Case II., No. 159. The minerals were probably developed by contact-metamorphism.

Among the changes which garnet undergoes that of conversion into *chlorite* is not uncommon. This is illustrated by the specimen No. 802. Here the crystals, while retaining their form, have become coated with a dull green chloritic mineral. The change generally occurs along microscopic cracks, the neighbouring garnet becoming less hard and dense, and gradually assuming a dull green appearance. Some fine pseudomorphs of chlorite after garnet are shown in the Wall Case 34, but these are not British specimens.†

*Chlorite* is a general name applied to a number of minerals, more or less scaly in structure and greenish in colour. They form a rather ill-defined group, consisting of silicates of aluminium and magnesium, with iron, etc., and since they contain a large proportion of water they are sometimes termed *hydromicas*. The chlorites are usually alteration-products of feldspars, garnet, mica, augite, hornblende, and other ferro-magnesian silicates; but in certain cases chlorite may be an original mineral. By the Cornish miner chlorite is commonly called *peach*, and hence a chloritic lode is said to be "peachy." Whilst the green peach is undoubtedly of this character, it seems that blue peach is usually a form of tourmaline.

The specimen No. 807 represents Cornish *Actinolite*, showing the radiating fibres of green colour and silky lustre characteristic of this form of amphibole.

No. 808 is a representative specimen of the mineral known as *Prehnite*. This is a hydrated silicate of aluminium and calcium,

\* "On the Occurrence of Metallic Ores with Garnet Rock," *Journ. R. Geol. Soc., Corn.*, vol. ix. (1878), p. 38. See also Solly in *Min. Mag.*, vol. vi. (1886). For ore-deposits formed by contact metamorphism, consult a valuable paper by W. Lindgren, "The Character and Genesis of certain Contact Deposits," *Trans. Am. Inst. Min. Eng.*, vol. xxxi. (1902), p. 226.

† On the alteration of garnet into chlorite see *Am. Journ. Sc.* [3], vol. x. (1875), p. 17, and vol. xxxii (1886), p. 307.



occurring in the cliffs near Botallack and at some other localities in St. Just. It will be subsequently noticed in connection with the fine specimens from Scotland (p. 216).

*Serpentine, etc. (Nos. 809 to 817).*

Among the various hydrous silicates shown in this case the most interesting is the mineral substance well known as *Serpentine*. This occurs, however, as a rock rather than as a definite mineral species. Several specimens of the beautiful rock from the Lizard district are placed here, under the numbers 809 to 813, and others are exhibited in Section IV. of the Horse-Shoe case; whilst a number of objects in the Hall of the Museum show the material worked as an ornamental stone in the form of columns, vases, etc. The origin of the Lizard serpentine has been specially studied by Prof. Bonney, who showed many years ago that it had been formed from the alteration of intrusive igneous rocks.\*

Serpentine usually results from the metamorphism of rocks rich in olivine, like the peridotites. Olivine, which is a silicate of magnesium, with more or less iron, is a mineral very prone to alteration. Its conversion into serpentine, a hydrous silicate of magnesium, can be traced as it proceeds along the cleavage cracks and curved fissures of the crystals. Pseudomorphs of serpentine after olivine are well known. Opaque granules of magnetite are usually present, and represent the iron eliminated from the olivine during serpentinisation; or the iron, passing wholly into the ferric state, may make its appearance as hæmatite or as limonite. The conversion into serpentine is accompanied by considerable increase of volume (above 30 per cent.), and probably involves reactions more complicated than simple hydration.

It was shown many years ago by the brothers Rogers that silicate of magnesium may be decomposed by carbonated waters.† This conclusion was confirmed by the experiments of Mr. A. Johnstone, of Edinburgh, who observed that water charged with carbonic acid attacks olivine.‡ Magnesium carbonate, or *Magnesite*, occurs in white veins and patches in the Lizard serpentine. The production of magnesite from serpentine evidently involves dehydration.

Mr. Howard Fox called attention some years ago to a substance curiously like flint, occurring as veins in the serpentine of Kynance Cove, and an analysis by Mr. Hort Player showed it to be the mineral called *pseudophite*.§ This mineral may, perhaps, be placed in the chlorite group (No. 815).

\* See especially his papers in *Quart. Journ. Geol. Soc.*, vol. xxxiii. (1877), p. 884; and vol. xxxiv. (1878), p. 769; *Geol. Mag.* n.s. [2], vol. vi. (1879), p. 362; and [3] vol. i. (1884), p. 406. See also Gen. M'Mahon's address "On the Manufacture of Serpentine in Nature's Laboratory," *Proc. Geol. Assoc.*, vol. xi. (1890), p. 427. Also: "British Petrography." By J. J. H. Teall, 1888, p. 104.

† *Amer. Journ. Soc.* [2], vol. v. (1848), p. 401.

‡ "On the action of carbonic acid water on olivine." *Proc. Roy. Soc. Edin.*, 1888.

§ *Min. Mag.*, vol. ix. (1892), p. 275.

*Steatite*, or *soapstone* (No. 816) occurs in the Lizard serpentine, and was at one time worked as a material for the manufacture of porcelain, as also as a source of various magnesian salts. It is a hydrous magnesium silicate, and may be regarded as a massive variety of talc. *Saponite* (No. 817) is a somewhat similar mineral, but contains much aluminium silicate.

With the Cornish serpentine is placed a specimen of *Diallage* (No. 814) from the gabbro of Crousa Downs, not far from the Lizard.\* The rock called gabbro is a crystalline aggregate of diallage and plagioclase felspar, with olivine. The dead-white mineral in the coarse gabbro is *saussurite*, an alteration-product of the plagioclase, whilst the diallage, which is a variety of augite, is distinguished by the bronzy lustre displayed by what appear to be its cleavage planes. These represent directions of chemical weakness along which the mineral has suffered that kind of alteration which Professor Judd has distinguished as *schillerisation*.† Microscopic lamellar enclosures have been developed along these planes of parting, and to these secondary minerals the metalloid lustre, or *schiller*, of the diallage is due.

#### *Allophane, etc. (Nos. 818 to 824).*

Several amorphous silicates of aluminium are here grouped together. The specimens 819 and 820, which attract the eye by their delicate blue colour and pearly lustre, are examples of the hydrated aluminium silicate termed *Allophane*. In these specimens the mineral occurs in small botryoidal masses, on black carbonaceous shale, from Wheal Hamblyn, near Bridestone, in Devonshire. The blue colour is due to admixture with some copper mineral, probably chrysocolla, as the cupreous allophane is said to pass in some cases into this copper silicate. The opaline allophane, like these specimens, has been distinguished as *Schrötterite*.

In No. 818 the allophane is tinted green, presumably by malachite, and is partially encrusted with brown hydrated oxide of iron, associated with a little native copper, in delicate sprigs, coated with the green carbonate. Allophane seems always to be a secondary mineral derived from various aluminous silicates, especially felspars. It is not infrequent in certain copper mines.

The massive opaque substance generally called *Lithomarge* is represented by Nos. 821 and 822. Some of the Cornish "lithomarge" may be referred to the species *halloysite*. In No. 822, from Tuckingmill, near Camborne, the white substance is marked with irregular stripes of purple colour. No. 823 represents the mineral from Restormel, which Prof. Church has distinguished as *Restormelite*.‡

\* For description of the Crousa Down gabbro see "British Petrography," by J. J. H. Teall, M.A., p. 174.

† On schillerisation see Prof. Judd's papers in *Quart. Journ. Geol. Soc.*, vol. xli. (1885), p. 383; and *Min. Mag.*, vol. vii. (1887), p. 81.

‡ *Journ. Chem. Soc.*, Vol. xxiii., (1870), p. 165.



The earthy substance, of dull green colour, numbered 824, is a sample of *Chloropal* from Haytor in Devonshire. This is a hydrated silicate of iron.

*Pigotite* (No. 825).

Under the name of *Pigotite*, Prof. Johnston, of Durham, described in 1840 a Cornish mineral which he regarded as a compound of alumina with an organic acid termed by him mudesous acid.\* To this body, in its anhydrous condition, he assigned the formula  $C_{12}H_5O_6$ . It was assumed that the acid had resulted from the decay of superficial vegetation on the moorland,† and having been carried down to a mass of decomposing granite had attacked the felspar. The product was found as an incrustation on the walls of certain caves in granitic cliffs in Cornwall. The specimens here exhibited from St. Levan, which have recently been presented by J. W. Wetherell, Esq., rather resemble a dark brown wood-opal.‡ The name was given to the mineral in compliment to the Rev. M. Pigot, who, with Prof. Johnston, first observed it.

*Retinite* (No. 826).

Associated with the Tertiary lignite of Bovey Tracey, in Devonshire, there are occasionally found small irregular masses of a brown resinous substance, usually earthy in appearance, such as the specimen No. 826. This substance was examined by Hatchett, who named it *Retinasphalt*, since he regarded it as partly resinous and partly bituminous.§ Subsequently it was analysed by Prof. J. F. W. Johnston of Durham.|| It is now usually designated *Retinite*, and appears to be a fossil resin exuded from the coniferous trees which contributed to the formation of the Bovey coal. The characteristic conifer is the *Sequoia couttsiae* of Heer, a tree allied to the mammoth tree of California.¶ It may be noted that the term 'retinite' is now used as a rather general name for a number of fossil resins more or less akin to amber, but usually occurring in lignite.

Various mineral hydrocarbons, including petroleum, have occasionally been found in some of the mines of Cornwall and Devon, and carbon in the form of *Graphite* is not unknown, as witnessed by specimens in the Horse-shoe Case, Section A.

The collection of British Minerals is continued in Case VII., on the opposite, or eastern, side of the Museum.

\* "On the constitution of Pigotite, and on the Mudesous and Mudesic Acids." *Phil. Mag.*, vol. xvii. (1840), p. 382.

† Hence the name, from *μύδηςσις* (*mudesis*), decay.

‡ "On the occurrence of Pigotite in the caves near Porthcurnow, St. Levan, Cornwall." By J. K. Creighton, *Geolog. Mag.* n.s. [iv.], vol. i. (1894), p. 223.

§ *Phil. Mag.* vol. xxi. (1805), p. 147.

|| "On the Composition of Certain Mineral Substances of Organic Origin." Part iv., "Retinasphalt." *Phil. Mag.*, vol. xii. (1838), p. 560.

¶ *Phil. Trans.*, vol. 152 (1863), p. 1051.

## CASE VII.

## DIVISION 1.

## MINERALS OF SOMERSETSHIRE, WALES, ETC.

## MINERALS OF WEST SOMERSET.

(Nos. 827 to 832).

The minerals of Cornwall and Devon, which have been described in the preceding pages, occupy six out of the twelve table-cases in which the Collection of British Minerals is installed. Justification for this disproportionate allocation of space may be found in the fact, previously stated, that these counties far surpass any other mining district of Britain in the number, the variety, and the beauty of their minerals. Moreover, the Ludlam Collection, as before remarked, is particularly rich in fine specimens from the mines of the two south-western counties.

Following the minerals of Cornwall and Devon, those of West Somerset may be conveniently considered. A few specimens of *Malachite* and *Azurite* exhibited in this case (Nos. 827 to 829) serve to recall the old attempts at copper-mining in the Triassic rocks on the north-east of the Quantocks. The principal workings were situated between Doddington and Nether Stowey. According to Mr. Leonard Horner,\* the Doddington copper mine had but a brief existence, the cost of pumping being greater than the value of the ore that was raised. The ore was principally a mixture of the green and blue carbonates, resulting from the alteration of copper-pyrites.

Of these two basic cupric carbonates, it is notable that the azurite, or blue ore, often occurs in crystals, whilst the associated malachite, or green ore, may be merely mammillary in form or fibrous in texture. The blue carbonate is a mineral of more limited occurrence than the green carbonate, into which it seems rather readily to pass.

By far the most important minerals in West Somerset are the *Iron-ores* of the Brendon Hills. These hills range in an east-and-west direction, about six miles south of the coast between Minehead and Watchet. They consist of rocks like much of the Cornish killas, and have been worked for slates at Treborough. In these slaty rocks, the iron-ore occurs in veins, which, according to the late Mr. Etheridge, occupy fault-fissures. The body of ore consists of *Chalybite*, or *Siderite*, occurring in cleavable crystalline masses,

---

\* "Sketch of the Geology of the South-western Part of Somersetshire." By Leonard Horner, Esq., F.R.S. *Trans. Geol. Soc.*, vol. iii. (1816), p. 383.



known as *spathose*, *sparry* or *spathic iron ore*; but this ferrous carbonate, being readily altered by superficial agencies, becomes converted in the upper part of the veins into brown and red oxides of iron. With these oxides the unaltered ore offers so strong a contrast by its pale fawn colour that it is known as "*white ore*." The Brendon iron-ores are represented by Nos. 831 to 832.

Like that of many other localities, the spathic ore of the Brendon Hills contains manganese—presumably in the form of carbonate, since manganous and ferrous carbonates are isomorphous. According to an analysis by Mr. J. Spiller, the ore contains as much as 12·64 per cent. of MnO.\* By superficial alteration, the manganese takes the form of hydroxide, so that the brown iron-ore at the outcrop is associated with much oxide of manganese. In consequence of the high proportion of manganese in the Brendon ore, it was peculiarly fitted for the manufacture of spiegeleisen, and at one time was largely worked for this purpose by the Ebbw Vale Company, and exported to South Wales. Relics of old workings show that the ore was wrought at a very early period, perhaps by the Romans. The mines and the ore have been described by Mr. Morgan Morgans,† who was in charge of the workings thirty years ago, and to whom the Museum is indebted for the interesting specimens in the tray No. 832, showing pseudomorphs of hæmatite after rhombohedra of chalybite.

Spathose ore, similar to that worked at the Gupworthy mine and elsewhere in the Brendon Hills, occurs under similar conditions, in the slaty rocks of Exmoor—a range extending from West Somerset into North Devon. According to the late Sir W. W. Smyth, the Exmoor veins course about E. 10° S.‡ The ferric hydroxide, resulting from the alteration of the spathose ore, occasionally takes the form of göthite, crystals of which line the cavities in the ore. No. 830 is a specimen of the Exmoor chalybite.

At Wheal Eliza, on Exmoor, the iron-ore was associated with disseminated copper-pyrites, and the vein was at one time worked for copper. Spathose ore is not infrequently accompanied by ores of copper and lead, notably by argentiferous galena—an occurrence illustrated at Weardale in Durham, where the ore occurs in Carboniferous Limestone.

In limestone districts, spathose ore may sometimes have been formed by the reaction of the carbonate of lime on ferrous sulphate from decomposed pyrites. But the ore of the Brendon Hills and Exmoor is not directly associated with limestone, though irregular

\* "*Metallurgy*." By John Percy, M.D., F.R.S. Vol. "*Iron and Steel*," 1864, pp. 210, 227.

† "*The Brendon Hills Spathose Iron Ore and Mines*." By Mr. Morgan Morgans. *Trans. South Wales Inst. of Engineers*, vol. vi. (1870), p. 79. Also "*On a Peculiarity of the Brendon Hills Spathose Iron Ore Veins*." *Quart. Journ. Geol. Soc.*, vol. xxv. (1869), p. 255. The peculiarity in question is the "end-slant" of the pockets of ore.

‡ "*On the Iron-ores of Exmoor*." By Warrington W. Smyth, Esq., F.R.S. *Quart. Journ. Geol. Soc.*, vol. xv. (1859), p. 105.

calcareous bands are not far off. Its occurrence rather recalls that of the spathose ore in the Duchy Peru lode in Cornwall, or more closely that of the fine deposits in the Devonian slaty rocks at Siegen in Westphalia. The carbonate of iron seems to have resulted not from a process of substitution, but rather from direct precipitation on the walls of the vein. The ore is accompanied by quartz. Possibly certain iron silicates in the rocks may have been decomposed by carbonic acid in the underground waters, with formation of ferrous carbonate and separation of silica.

At the present time no iron ore is raised either from the Brendon Hills or from Exmoor.

### MINERALS OF THE MENDIPS.

(Nos. 833 to 845).

Whilst the Mendip Hills have given their name to a rare mineral, *Mendipite*, it is said, on the other hand, that they received their name from their mineral wealth, the modern term Mendips being a corruption of the old term "Myne Deeps." The principal minerals are the ores of lead and zinc, though minerals containing copper and manganese are not unknown, whilst iron-ore is in some places rather abundant.

The Mendip plateau is a stretch of high ground in Somersetshire, extending from near Frome in a north-westerly direction as far as the Bristol Channel, a little south of Weston-super-Mare. It thus forms a broad belt of table-land, about thirty miles long, though not more than five miles in width, running in a N.W. and S.E. direction, and reaching a maximum height of 1,060 feet. Its geological structure has been described by Mr. H. B. Woodward, F.R.S.\*

The Mendip range consists of Carboniferous strata, resting conformably on Old Red Sandstone. These strata have been thrown into a succession of anticlines, having their axes striking E. and W., and the summits of the folds have suffered denudation, so that the Old Red Sandstone, forming the nucleus of the range, is here and there exposed. Patches of Dolomitic Conglomerate—an old beach deposit of Triassic age—rest unconformably on the upturned and denuded edges of the Carboniferous strata. Much of this conglomerate has no doubt been removed by denudation; yet fragments still lie on the flanks of the hills and in some places cap the high ground. It is this Dolomitic Conglomerate and the Carboniferous Limestone which form the principal repositories of the minerals of the Mendips.

### *Lead-Ores* (Nos. 835 to 837).

So far as the lead-ore is concerned, it is certain that it engaged the attention of the Romans, and probably it had not been overlooked even in pre-Roman days. Pigs of lead bearing Roman inscriptions,

---

\* "Geology of East Somerset and the Bristol Coal-fields." Mem. Geolog. Survey, 1876. Also: *Proc. Geol. Assoc.*, vol. xi. (1891), p. 481. The Survey Memoir contains a "List of Minerals found in the Area." p. 176.



with ruins of smelting houses rich in relics of Roman occupation, in the shape of pottery and coins, have been discovered at Charterhouse, between Priddy and Blagdon.\* So extensive were the early smelting operations that in recent years the old waste heaps of slag, and even the slimes and tailings, have been re-worked. This refuse matter has been found to contain on an average about 12 per cent. of metallic lead. It consists of materials belonging to various periods of working, but it is not unlikely that in some cases the modern workman is re-handling the very refuse of the Roman smelter.

In this refuse, as in the old Roman lead-slugs of Laurion, in Greece, various secondary minerals have been developed ; and among these, Mr. L. J. Spencer, of the British Museum, has detected the rare mineral *Leadhillite*.† This was found in cavities of slag, which occurred in association with fragments of charcoal and masses of galena, only partially fused. Some of the lead had been converted into carbonate, sulphate and sulphato-carbonate, which had crystallised in the free spaces, and thus afforded an interesting illustration of the recent formation of the oxidised lead-minerals known respectively as cerussite, anglesite and leadhillite.

The primitive lead ore of the Mendips, as elsewhere, is *Galena* (Nos. 835, 836). According to Mr. T. Morgans,‡ the lead-ore occurs chiefly in the form of lumps of galena, associated with the oxides of manganese and iron, in veins of clay, filling fissures which seem to run mostly along joint-planes. Strings and nests of galena occur both in the Carboniferous Limestone and in the Dolomitic Conglomerate, often associated with more or less cerussite, or lead carbonate, and with a matrix principally of calcite. As the "old men" or "groovers," as the miners of bygone days are called, were prevented from deep working by the trouble of water, they were confined to limits, rarely, if ever, exceeding, and but rarely reaching, a depth of thirty fathoms.

#### *Mendipite* (Nos. 839, 840).

The two specimens, Nos. 839 and 840, are examples of the rare mineral called *Mendipite*. It appears that an old specimen labelled "Lead spar from Mendip" was examined by Berzelius in 1823, and determined to be an oxychloride of lead ; and to this species Glocker in 1839 gave the name by which it has ever since been known. The specimens exhibited are from Churchill, the original locality, and show the mineral associated with oxide of manganese.§ It will be seen that the mendipite forms crystalline cleavable masses, of

\* See Prebendary Scarth : *Journ. Archæolog. Assoc.*, vol. XXI. (1875), p. 129.

† "Leadhillite in Ancient Lead Slags from the Mendip Hills." *Rep. Brit. Assoc.*, for 1898, p. 875.

‡ "Notes on the Lead Industry of the Mendip Hills." *Trans. Inst. Mining Eng.*, vol. xx. (1902), p. 478.

§ From this locality the mineral has sometimes been called *Churchillite*, but the name is now obsolete.

columnar structure, yellowish white in colour and slightly adamantine in lustre. The mineral belongs to the orthorhombic system, but distinct crystals are unknown.

Mendipite was discovered some years ago near Priddy, in the workings of the Somerset Manganese and Iron Company.\* It there occurs in the Dolomitic Conglomerate, associated with a little copper-ore and oxide of manganese.

The oxychloride of lead is no doubt a secondary mineral, derived directly or indirectly from the alteration of galena. At Churchill it occurred with galena, and at Priddy with cerussite. The occurrence of an oxychloride suggests that waters containing chlorides have been active in the oxidation-zone of the mineral-deposit. Possibly Triassic rocks, more or less saliferous, once spread over this area. But, apart from such strata, the analysis of ordinary sedimentary rocks frequently reveals the presence of chlorides, and moreover, in inland fresh waters, chlorides are sufficiently common. According to Prof. E. Kinch the annual average amount of common salt in the rain-water falling at Cirencester is as much as 36 lbs. per acre.†

It is not surprising, then, that meteoric waters percolating through deposits of lead-ore may sometimes give rise to the formation of chlorides, such as are occasionally found in the shallow parts of certain ore-bodies, and are represented in the Mendip area by mendipite.

#### *Zinc-ores (No. 838).*

The zinc-ore formerly worked on a large scale in the Mendips was chiefly in the form of the carbonate called *Calamine*. Some confusion has, unfortunately, arisen in mineralogical nomenclature with regard to this word. In England the term "calamine" is commonly applied to the carbonate of zinc, whilst elsewhere the word is frequently used by mineralogists to denote the hydrous silicate, whilst the carbonate is designated as Smithsonite. By miners, the term "calamine" is often applied indifferently to both carbonate and silicate, and it appears that both species were included under the old name of *lapis calaminaris*.‡ The separation was first distinctly pointed out by James Smithson, who analysed the minerals a century ago, and apologised for the imperfection of his work on the ground that "chemistry is yet so new a science."§ An example of the calamine is furnished by No. 838.

It was not until the early part of the eighteenth century that the value of calamine as an ore came to be recognised. At that time, it

\* *Proc. Geolog. Assoc.*, vol. xi. (1891), p. excix. The history of mendipite is here given by Mr. H. B. Woodward, F.R.S.

† *Journ. Chem. Soc.*, 1900, Part i., p. 1271. This estimate is based on investigations carried on for the last twenty-six years, and it assumes that all the chlorine in the rain occurs as sodium chloride. See also recent analyses by Mr. W. W. Fisher in *The Analyst*, 1904.

‡ See "The Nomenclature of Zinc-ores." By W. R. Ingalls. *Trans. Am. Inst. Min. Eng.*, vol. xxv. (1896), p. 17.

§ "A Chemical Analysis of some Calamines." By James Smithson, F.R.S. *Phil. Trans.*, vol. xciii. (1803), p. 12



came into use not so much for the production of metallic zinc, or spelter, as for the preparation of yellow metal, or brass. The calamine was worked chiefly at Rowberrow, Shipham, and Harptree; and the calcined ore was sent to the brass-houses of Bristol and Birmingham.

Most of the calamine of the Mendips was found in the Dolomitic Conglomerate, where it occurred partly as veins and partly disseminated through the rock, often in small fragments resembling gravel. It was probably derived from the alteration of zinc-blende, the common ore of zinc. Oxidation of the blende, which is a sulphide of the metal, produces sulphate of zinc, which, reacting with the limestone or with the dolomite, might form zinc carbonate. Deposits of calamine may occur even in deep-seated zones, if within reach of fissures which have afforded a channel for the descent of surface waters. M. Lodin's views on the formation of calamine are referred to at p. 142.

Although zinc-blende seems to be a very rare mineral in the Mendips, it probably exists at considerable depth as the primary ore of zinc. It rarely happens that ore-deposits which contain galena are destitute of blende, but it is common for the blende to occupy a deeper zone. Galena is a rather stable sulphide, whilst blende is more readily attacked by meteoric agencies, and easily converted into oxidised compounds like the sulphate and carbonate.

Calamine is a common and characteristic mineral in dolomite. Dieulafait showed that it might be assumed, on thermo-chemical principles, that the formation of calamine from zinc sulphate was more likely to occur by reaction with magnesium carbonate than with calcium carbonate.\* It is notable that generally the occurrence of ores, both of lead and zinc, seems to be more common in limestones which are magnesian than in those of normal type. The dolomitic rock lends itself readily to metasomatic replacement†; and as Mr. H. F. Bain has pointed out, the porous, or even cavernous, texture of magnesian limestone must favour the circulation of underground waters, and so promote chemical changes.‡

Calamine does occur, however, in the Carboniferous Limestone of the Mendip area; and pseudomorphs are known in which zinc carbonate has taken the form of fine scalenohedra of calcite, such as might occur in fissures of the limestone.§

#### *Iron-ores* (Nos. 833, 834).

*Iron-ores* are of very common occurrence in the Dolomitic Conglomerate. The brown and red oxides are to be found, as Mr. Etheridge remarked, wherever the conglomerate rests on the Carboniferous Limestone, on the Millstone Grit, or on the Pennant Grit.

---

\* *Comptes Rendus*, vol. ci. (1885), p. 842.

† *Metasomatism* is a term used to express a change of substance in a mineral body, effected usually by hydro-chemical action. It differs from pseudomorphism since it does not necessarily connote retention of form.

‡ *U. S. Geol. Surv.*, 22nd. Ann. Rep., Part ii., 1901, p. 209.

§ For further remarks on Calamine see pp. 141, 166.

It occurs not only in the conglomerate itself, but also in faults, fissures, and pockets in the underlying Carboniferous rocks. It has been suggested that the iron oxides of these Carboniferous deposits have been derived in many cases from red rocks, Triassic or Permian, by which they have at some time been overlain. The specimen No. 834 represents the iron-ores of the Mendips.

It was from the Dolomitic Conglomerate, resting on Carboniferous Limestone and Millstone Grit, that the red ochre called *reddle* or *ruddle* was at one time extensively extracted at Heath Hill, south of Winford, on the north of the Mendip area. Pits reaching in some cases to more than fifty feet in depth, were sunk.\* The reddle was an argillaceous ferric oxide, forming a deposit which reached as much as six feet in thickness. The mineral has also been extensively worked in recent years.

*Potato-stones (Nos. 842 to 846).*

Among the minerals of the Dolomitic Conglomerate mention should be made of the curious siliceous nodules known as *Potato-stones*. A small series of these nodules is here exhibited (Nos. 842 to 845). They are rather widely distributed, occurring south and east of the Mendips, near Wells and Cheddar, and on the north at Clevedon, and also at several localities near Bristol.

The potato-stones present usually a crust of chalcedonic silica, rough on the outside, and lined internally with crystals of quartz. Other minerals, such as calcite and celestite, are also found sub-ordinately inside the geodes. Prof. Rupert Jones, from the study of a large collection in the Museum of the Geological Society, was led many years ago to suggest that the nodules had their origin in the replacement of limestone by silica.† This suggestion seems highly probable.

In the Dolomitic Conglomerate there are numerous fragments and pebbles of Carboniferous Limestone, united by a cement which is more or less magnesio-calcareous or dolomitic. Such pebbles might readily undergo metasomatic alteration, whereby the carbonate of lime was gradually removed and silica deposited in its place, with more or less retention of external form. The molecular substitution of silica for calcium carbonate is a change which has come to be widely recognised by chemical geologists. The process of replacement, starting from the exterior of the nodules, was usually not continued far enough to form a solid siliceous mass. Water, gaining access to the interior of the mass, might remove the central calcareous part, leaving a hollow in which siliceous solutions slowly deposited crystalline quartz as a lining of the geode. In some cases chalcedonic layers alternated with deposits of a distinctly crystalline character, and a true agate, with a regular succession of zones,

\* *Trans. Geol. Soc.*, 2nd series, vol. i. (1824), p. 368.

† "On Quartz, Chalcedony, Agate, Flint, Chert, Jasper, and Other Forms of Silica Geologically Considered." By Prof. T. Rupert Jones, F.R.S. *Proc. Geol. Assoc.*, vol. iv. (1876), p. 439.



was produced. Probably the chemical activities of the circulating waters were accelerated by heat; and the siliceous solutions saturating the rock, perhaps buried at a considerable depth, deposited crystalline minerals in all accessible situations, so that the cavities between the fragments of the breccia are in some cases lined with crystals.

Some of the potato-stones exhibited here, and in a table-case on the opposite side of the room, were presented by Spencer G. Perceval, Esq., of Henbury, and others by the late Swinfen Jordan, Esq. Several of them display beautiful agates in their interior.

### MINERALS OF THE BRISTOL DISTRICT.

(Nos. 847 to 858).

Many of the minerals already noticed as occurring in the Mendips, re-appear under similar geological conditions in the neighbourhood of Bristol. At the same time each district has certain minerals peculiar to itself. A list of the minerals occurring in the neighbourhood of Bristol, prepared by Mr. E. Wethered, has been published by the Cotteswold Club.\*

Galena and copper-ores occur in small quantity in the Dolomitic Conglomerate; manganese is rather widely distributed; and iron-ores, in the form of hæmatite and limonite, occur in such abundance as to be occasionally worked commercially.

#### *Iron-ores, etc. (Nos. 847 to 854).*

Rather more than thirty years ago an iron-mine was opened in the Royal York Crescent at Clifton, and was described by Mr. J. G. Grenfell. It was sunk in the Millstone Grit, which is overlain by Triassic strata rich in iron. The principal ore was limonite, but this was associated with hæmatite, often found in the interior of the lumps of ore, and with göthite, occurring sparingly in crystals.†

Some of the specimens here exhibited show the limonite in stalactitic forms (Nos. 847, 850); and from the vertical position of the stalactites in the cavities of the ore it seems, as Mr. Grenfell pointed out, that their formation must have been subsequent to the movements which tilted the enclosing rocks.

At Iron Acton, Frampton Cottrell, and some other localities north of Bristol, which have yielded much hæmatitic iron ore, the mineral occurs in the Pennant Grit, which is referable to the Middle series of Coal Measures. The ore has no doubt been introduced, as Mr. Etheridge suggested, from the iron-bearing Triassic or other red rocks which overlie, or at some time have overlain, these strata.‡

\* *Proc. Cotteswold Club*, vol. viii. (1886), p. 30.

† *Trans. Clifton Coll. Sci. Soc.*, Part iv., p. 46; *Geol. Mag.* (n. s.) vol. i. (1874), p. 179.

‡ *Quart. Journ. Geol. Soc.*, vol. xxvi. (1870), p. 183. *Proc. Cotteswold Nat. Club*, vol. iv. (1868), p. 47.

From the upper beds the iron may have migrated downwards, by means of descending solutions, and the impregnation of the Carboniferous rocks and the infilling of their cavities with iron oxides may be a process which, as Mr. H. B. Woodward remarks, is in some cases even still in progress.\*

On some of the specimens of Bristol iron-ore here exhibited, such as No. 852, the limonite carries beautifully defined crystals of quartz. It will be noted that some of the crystals are doubly terminated; that is to say, the six-sided prism is attached by one of its lateral faces to the matrix, whilst each of the free ends is capped by a six-faced pyramid. The brilliant crystals of quartz in several of the specimens (Nos. 851, 854) display a red colour, more or less pronounced, due to enclosed oxide of iron, and recalling the specimens of *Eisenkiesel* from the Restormel Royal Iron Mine in Cornwall (p. 92). Many of the crystals of red quartz have been derived from the interior of the potato-stones found near Bristol. The small but well-defined crystals in the tray No. 846 have been obtained from such a source; some of them are bi-pyramids of quartz, whilst others are scalenohedra of calcite. The quartz crystals, when colourless and pellucid, are sometimes known as *Bristol Diamonds*, or *Bristol Stone*. In No. 841, crystals of calcite, tinted pink with oxide of iron, are seen studding the walls of a geode; and occasionally celestite may be found in a similar position.

#### *Celestite* (Nos. 855 to 858).

To the student of mineralogy the *Celestite* or *celestine*†, a native sulphate of strontium, is the most interesting of all the minerals occurring in the neighbourhood of Bristol. Several representative specimens are here shown (Nos. 855 to 857), but with these the visitor should compare the suite of specimens in the Central Horse-shoe Case (Section G), which includes some examples of this mineral exceptional for size and beauty.

The celestite of Bristol occurs in the lower beds of the Keuper marls. At Clifton and Durdham Downs it has been found in the Carboniferous Limestone, not however in the rock itself, but simply in fissures to which it has probably gained access from overlying Triassic strata. Mr. H. B. Woodward cites a number of localities which yield celestite in the district of Bristol and East Somersetshire,‡ including some in the Oolites and the Rhætic beds.

Some of the finest crystallised specimens were obtained from Pyle Hill, when the Bristol and Exeter Railway was in course of construction. Other specimens, of remarkable size and perfection

\* *Mem. Geol. Surv., E. Somersetshire and Bristol Coal-fields*, 1876, p. 166.

† *Celestine* is the usual form of the word, but Dana many years ago advocated the general use of the termination *-ite* in mineral names. The ending in *-ine* is chemical rather than mineralogical.

‡ *Op. cit.*, p. 176. See also: "Observations on Celestite." By Frederick Smithe. *Proc. Cotteswold Club*, vol. x., (1892), p. 71. "Celestine Deposits of the Bristol District." By B. A. Baker. *Proc. Brit. Nat. Soc.*, vol. ix (1902), p. 161



of form, have been found at Wickwar and at Yate, in Gloucestershire, where large deposits were discovered some years ago. The collection contains representative specimens from all these localities, those from Yate having been presented by the late H. G. Madan, Esq., who was intimately acquainted with the locality and with the mineral.

None of the Bristol celestite presents the celestial blue colour, suggested by the name of the species; yet a delicate bluish tint is often visible. This has been referred to the presence of a ferros-ferric phosphate, but the late Mr. W. W. Stoddart, who examined many of the bluish specimens, failed to detect in them any trace of iron.\* The reddish tint of much of the celestite is, however, due to ferric oxide. Mr. Stoddart made the interesting observation that many plants growing on the celestite-bearing marls near Bristol contained strontium, which was readily detected in their ashes by the spectroscope; whilst the same species growing in the neighbourhood, but off the marls, were destitute of this element.

Although celestite is found in veins, and as irregular masses in the Keuper marl, some of the finest specimens are obtained from the interior of geodes. The large crystals, of prismatic habit and in some cases of tabular form, found in these cavities are often associated with selenite. Such a companionship seems indeed to be almost universal in the Bristol area. The association of celestite and gypsum is illustrated by the specimen No. 1401 in Case XI. As a matter of fact, most gypsum contains more or less strontium.

Strontium is an element much more widely diffused than was formerly suspected, although its concentration in notable quantity is comparatively rare. M. Dieulafait found it in many mineral springs and in sea-water, as well as in the hard structures of certain marine organisms.† According to the analyses of Dr. W. F. Hillebrand, barium and strontium are widely distributed in rocks, though the proportion is usually below 0.1 per cent.‡ The water of the dropping well at Knaresborough, derived from Permian strata, contains, according to Mr. B. A. Burrell, 0.322 grains of strontium per gallon, equivalent to 0.672 of strontium sulphate.§ The sulphate is present in the deposit from water pumped up from certain collieries in Durham, as analysed by Professor Clowes.|| In many of the old well-waters of Bristol strontium occurs, derived no doubt from the celestite in the marl through which the water has percolated.

\* "On the Occurrence of Celestine in the Keuper Marls, and its Influence on the Composition of Plants." *Min. Mag.*, vol. i. (1877), p. 4.

† *Comptes Rendus*, vol. lxxiv. (1877), p. 1303.

‡ *Journ. Chem. Soc.*, 1896, Abstracts, part ii., p. 191.

§ *Proc. Yorkshire Geol. and Polyt. Soc.*, new ser., vol. xiii. (1895-1899), p. 135.

|| *Report Brit. Assoc.*, Newcastle-upon-Tyne, 1890, p. 596.

It is worth noting that celestite has been found, with calcite, fluor, and galena, in the vein-deposits of the thermal springs of Bourbon-l'Archambault, in the Department of the Allier.\*

The sulphate of strontium being much more soluble in water than is the corresponding salt of barium, is more frequently found in natural waters. Yet as a mineral, barytes is far more common than celestite. The two species are isomorphous, crystallising in the orthorhombic system, and often assuming a similar habit.

Probably the origin of the celestite in the West of England is to be traced to the strontium salts in sea-water or in salt lakes. In some cases, celestite is believed to owe its formation to the action of sulphate of iron, from decomposing pyrites, on strontianite, or the carbonate of strontium; but strontianite is not recorded among the minerals of the Bristol area. The connection between celestite and selenite, already noticed, suggests a common origin for the two sulphates. Dieulafait found that on the spontaneous evaporation of sea-water, the strontium was accumulated chiefly in the gypseous deposit, and not in the sea-salt.

The deposits of celestite in Gloucestershire and Somersetshire are not without economic importance. According to the official statistics † the quantity obtained from shallow quarries in these two counties and shipped from Bristol Docks during the year 1902 amounted to 32,281 tons, of the value of as many pounds sterling.

Large quantities of celestite are employed in Germany in the preparation of beet-root sugar. For sugar refining, the innocuous compounds of strontium have superseded those of barium, the barium salts being poisonous. The celestite is converted into strontium hydrate, which is extensively used in Scheibler's process for separating the sugar as a strontium saccharate.‡ Celestite also finds application as a source of other strontium salts, such as the nitrate, which is used for giving a crimson light in pyrotechny.

The occurrence of celestite, associated with calcite, in cavities of the Keuper marl under the summit of Peak Hill, near Sidmouth, in Devonshire, has been recorded by Mr. Spencer G. Perceval.§ and specimens of the mineral from this locality, exhibited in the Horse-shoe Case, may be compared with the mineral from the Somersetshire and Gloucestershire localities.

Since the sulphates of strontium and barium are isomorphous, it is not surprising that the two salts should occur in natural union. Such a mineral is distinguished as *Barytocelestite*, or *barytocelestine*. In digging the foundation of buildings a few years ago in Oakley Road, Clifton, a mineral unearthed from the Keuper marl was detected as barytocelestite by Mr. W. H. Wickes. A specimen

\* *Comptes Rendus*, vol. lxxx. (1875), p. 1297.

† Home Office Report: Mines and Quarries for 1902. Part iii., Output, Edited by C. Le Neve Foster, D.Sc., F.R.S., p. 275.

‡ Thorpe's "Dictionary of Applied Chemistry," vol. iii., pp. 603, 623.

§ "On the occurrence of Celestine in New Red Marl, near Sidmouth." *Min. Mag.*, vol. iii. (1880), p. 255.



presented by him, is here shown as No. 858.\* An analysis of a specimen from the railway cutting at Chipping Sodbury has been made by Dr. Pollard in the laboratory of the Geological Survey.†

### MINERALS OF THE FOREST OF DEAN.

(Nos. 859 to 862).

Extensive deposits of iron-ore occur in the upper part of the Carboniferous Limestone and in the lower part of the Millstone Grit, which crop out as a narrow zone engirdling the little coal-field of the Forest of Dean, situated between the Severn and the Wye. The ore is principally *Limonite*, or brown hydrated oxide, associated with a little red hæmatite and with reddle, or ochre, which occurs in a thin vein at the base of the mine-measures. The ore-bearing limestone is known locally as *crease*, or *crease stone*. In this rock the ore occurs in the form of irregular pockets, connected by strings or leads, and the removal of the ore leaves caverns, frequently of vast dimensions, called *churns*. These irregular spaces, with their limestone buttresses, often have calcareous stalactites pendant from the roof or bedecking the walls, and present many of the picturesque features of limestone caverns. No. 862 is a specimen of calcite crystallised around a stalactitic deposit from one of these churns.

It has often been suggested that the limestone was originally cavernous, and that the ore was deposited in such pre-existing spaces; but it seems more probable that the removal of the limestone and the deposition of the ore were concurrent processes, or rather perhaps that the iron oxide has taken the place of the calcium carbonate by molecular replacement. This metasomatic action will be again referred to, in connection with the hæmatite deposits of the North of England.

Three kinds of brown iron-ore are recognised in the Forest of Dean‡, namely: (1) *Brush-ore*, or limonite in stalactitic, reniform, or compact masses, sometimes fibrous and radiate in structure, and occasionally coated with minute crystals of ferric hydrate, so black and brilliant as to impart a velvety appearance to the surface. (2) *Smith-ore*, an incoherent form of limonite, often in a finely powdered condition, and less rich in iron than the brush-ore.§ (3) *Clod*, a highly ferruginous marl, useful as a flux in smelting the ore.

No. 859 is an example of brush-ore, No. 860 of smith-ore, and No. 861 of grey ore, an ore in which the limonite is associated with chalybite.

\* *Proc. Geol. Assoc.*, vol. xvi. (1900), p. 423. See also, Norman Collie in *Bristol Nat. Hist. Soc.*, 1879: and, Mark Stirrup, *Trans. Manchester Geol. Soc.*, vol. xxvi. (1901), p. 487.

† *Geol. Surv.*, Summary of Progress for 1902, p. 60.

‡ On the ores of this locality consult: "The Ironstone Formation of the Forest of Dean; with a sketch of the General Geology and Industrial History of the District." By Dr. J. W. Watson. *The Geologist*, vol. i. (1858), pp 217, 265. See also, *Proc. Cotteswold Club*, vol. viii., p. 32; vol. x., p. 220.

§ The smith-ore may yield from 54 to 58 per cent. of ferric oxide, whilst the brush-ore may contain, when pure, 80 per cent

The iron-ores of the Forest of Dean were worked certainly in the Roman period, perhaps even earlier. Vast cinder heaps, or accumulations of old slags, are still found in the Forest, and occasionally declare their age by yielding a Roman coin or other characteristic relic. The remains of the ancient workings are known as *scowles*.\*

Although ironstone-mining in this locality has declined in recent years, it is by no means extinct. According to the Home Office statistics the amount of brown iron-ore raised in the Forest of Dean during the year 1902 was 5,738 tons.

*Iron-pyrites* occurs in masses, locally called "dogs," in a vein of coal known in the Forest as the "Twenty Inches." A list of the minerals of the Forest of Dean was published by the late Mr. W. H. Fryer, of Coleford, in the *Proc. Cotteswold Club*, vol. viii., p. 32; and a general list of the minerals of Gloucestershire was given by the late Rev. Dr. Smithe, of Churchdown, in the same publication, vol. viii. p., 33.

#### MINERALS OF SOUTH WALES.

(Nos. 863 to 874).

As in the little coalfield of the Forest of Dean, so in the vast field of South Wales, the Carboniferous Limestone contains, at least along the southern margin of the basin, occasional pockets of iron-ore, including both the red oxide, or *Hæmatite*, and the brown oxide, or *Limonite*.† These ores occur in irregular deposits, often lying more or less directly along the planes of bedding and jointing of the limestone suggesting the introduction of the iron from solutions running along the easiest path offered by any planes of weakness. In some cases the ore appears to occur in the body of the limestone, as at the old Garth Mine, at Penttyrch; in others at the junction of the limestone and the Millstone Grit shales, with Dolomitic Conglomerate above, as at Mwyndy, near Llantrissant, where the ore also occupies vertical fissures in the limestone; and in other cases again the ore occurs between the Carboniferous Limestone and the shales, and at the junction of the Carboniferous strata with the overlying Dolomitic Conglomerate, as at the Trecastle Mine. Mr. Stephen Vivian has illustrated these several modes of occurrence. It often happens that whilst the limestone forms the footwall, the shale may form the hanging wall; the grit being absent.

Specimens of the hæmatite, or red ore (Nos. 863, 864) show its general resemblance to the ores of Ulverston and of Whitehaven (p. 144), and any explanation of the origin of the one will probably apply to that of the others. Some of the South Wales hæmatite is highly siliceous, forming the stone called "blue ore." It seems to

\* "The Forest of Dean; an Historical and Descriptive Account." By [Rev.] H. G. Nicholls, M.A. 1858.

† See "The Hæmatite Deposits of the southern Outcrop of the Carboniferous Limestone of South Wales." By W. Stephen Vivian. *Trans. S. Wales Inst. Eng.*, vol. xiv. (1884-86), p. 164.

Also Mr. Strahan's *Geolog. Surv. Mem. on Geology of the Country around Newport*, 1899.



have been suffused with siliceous solutions, and crystals of quartz not infrequently are found lining cavities in the ore. No. 868 is a specimen from the old Mwyndy mine, showing beautiful crystals of quartz, colourless and limpid, with enclosures of limonite in the form of parallel rods or needles. The ore is said to become less siliceous in depth, and passes in some places into soft ochre.

Whether the source of the iron were the coal-measure ironstones, as has been suggested, or, as seems much more likely, the red rocks of the Dolomitic Conglomerate, or other Triassic strata, which probably once covered much of the country, the iron seems to have been carried downwards in solution, and to have partially replaced the limestone. Probably ferrous carbonate was first formed, and this subsequently converted into oxide. Chalybite, however, though not unknown, is a mineral of exceptional occurrence here. The formation of the ore by metasomatic replacement has been studied by Mr. E. Wethered,\* Prof. Howard † and Mr. A. Strahan.‡

Conclusive evidence of the substitution of ferric oxide for calcite in the limestones of South Wales is furnished by Mr. Strahan, who has figured a microscopic section of Carboniferous Limestone from Rhubina, in which organic structures, representing crinoids and polyzoa, have been replaced by red oxide of iron.§

The specimen No. 869, presented by H. H. Thomas, Esq., shows excellent crystals of *ferriferous dolomite* from the Lower Coal-measure sandstone of Park Colliery, Tirydial, S. Wales.

*Manganese ore* has occurred at the Trecastle Mine and *ores of lead and copper* are also found occasionally in the Carboniferous Limestone; whilst galena is by no means uncommon in the Dolomitic Conglomerate. No. 865 is a specimen of galena, and No. 866 one of copper-pyrites, both from the Carboniferous Limestone of Mynydd-y-Gareg, Kidwelly, presented by E. E. L. Dixon, Esq.

The occurrence of *galena* in the coal-measures has been frequently observed, not only in South Wales but in several other localities. The late Mr. E. Rogers recorded a case in which a seam of coal in the Pennant series at Abercarn was traversed by an impersistent vein, consisting of iron pyrites, galena and calcite. The coal in the immediate neighbourhood of the lode exhibited no evidence of the action of heat,|| and the minerals were no doubt deposited in the wet way. The unusual occurrence of galena in the underclay of a coal-seam near Coed-Ely, has been noted by Mr. Strahan in the Geol. Surv. Memoir on Pontypridd (p. 81).

\* "On the Origin of the Hæmatite Deposits in the Carboniferous Limestone." *Geol. Mag.* [N. S.] Dec. ii, vol. ix. (1882), p. 522.

† "The Hæmatite Deposits of South Wales and the Theories regarding their Formation." *Trans. Cardiff Nat. Soc.*, vol. xxvi., Part 1 (1894), p. 47.

‡ "The Geology of the South Wales Coal-field, Part I. The Country around Newport." By Aubrey Strahan, M.A., 1899.

§ *Ibid.* Plate, fig. B.

|| "On the occurrence of a metalliferous vein of lead, passing through a coal bed in South Wales." *Trans. South Wales Inst. Engineers*, vol. i. (1859), p. 228.

*Iron-pyrites* is common in the Coal-measures of South Wales, as in other coal districts. It occurs either as impure nodules and bands, or as films on the joints and partings of the coal, or again disseminated through the coal itself. It is often termed by miners *brasses*, whilst pyritic seams are known as *brass veins*. Some of the material so called in South Wales contains, however, but very little pyrites, and the late Mr. W. Adams remarked that the *Duffryn Brass* is really an iron ore with only a small percentage of pyrites.\* In addition to the ordinary form of 'visible yellow pyrites,' the mineral also occurs so intimately associated with the coal as to escape ocular observation, and in this state has been called '*black pyrites*.'† The specimen of pyrites in coal (No. 867) is from near Kidwelly.

It is easy to understand how sulphide of iron might be formed in the coal-measures by the reducing action of decomposing vegetable matter on solutions containing sulphates with iron-salts. In some cases its formation may have been contemporaneous with that of the coal, but where the mineral occurs along the joints of the fuel it must evidently have been of subsequent formation.

A large series of specimens of *Clay-ironstone* from the South Wales coalfield is displayed in the Wall-cases 50 to 54.‡ This ironstone is a very impure form of ferrous carbonate, of variable composition but containing 25 to 35 per cent. of metallic iron. It either occurs as nodules called *balls*, distributed through the shales, or is spread out as distinct beds or veins known as *pins*. By miners the stone is generally termed *mine*—a word frequently applied elsewhere to ores of iron. Although they have now lost much of their former importance, these clay ironstones formed, during the first half of the nineteenth century, the staple raw material of the iron industry of the country. In some cases the ferrous carbonate of the coal-measures is associated with much bituminous matter, and is then known, from its colour, as *black band ironstone*.

It is not unlikely that the original source of much of the iron in the coal-measures may be traced to the iron-bearing silicates of the crystalline rocks. Such silicates may be decomposed even by ordinary meteoric waters charged with carbonic acid. Under oxidising influences the ferrous carbonate would readily suffer alteration, but by the reducing action of decomposing organic matter might be retained in the ferrous condition. This precipitated carbonate

\* "On the 'Coal Brasses' of the South Wales Coal-fields," *Trans. South Wales Inst. Eng.*, vol. v. (1867), p. 190.

† See Mr. Strahan's Notes in Blue-book, *Roy. Com. on Arsenical Poisoning*, vol. ii (1903), p. 303.

‡ For a description of the ironstones of South Wales see several memoirs of the Geological Survey, viz: "The Ironstones of Great Britain," Part iii. 1861; Mr. A. Strahan's "Geology of the South Wales Coal Field," Part i. (Newport) 1899; Part ii. (Abergavenny) 1900; Part iv. (Pontypridd and Maes-teg) 1903. The origin of the clay iron ore is discussed by Sir H. T. De la Beche and by Mr. R. Huntin vol. i. of the "Memoirs of the Geological Survey."



might be mingled with the mud of the coal-measures or possibly be introduced after it had hardened into shale. In the case of the balls, an organism seems in many cases to have served as a nucleus, and the impure carbonate has gathered round this centre of aggregation, much in the same way as that in which the septaria of other argillaceous formations have been formed (No. 870). Some of the clay ironstone nodules show successive zones of concretionary deposits around an organic nucleus. Nodules of iron carbonate are known sometimes as *Sphærosiderite*. Fissures of contraction may occur in these nodules, as in ordinary septaria, and on the walls of these cracks certain minerals have sometimes crystallised. The specimen No. 871 shows crystals of quartz and calcite in the shrinkage cracks of an ironstone from Merthyr Tydfil. Metallic sulphides are also occasionally found in such situations; and the occurrence of such minerals as galena, blende and millerite, associated perhaps with quartz, calcite and barytes, suggests the manner in which certain mineral veins may have been filled. A series of specimens illustrating these miniature ore-deposits is exhibited in Wall-case 24.

*Millerite.* (No. 872.)

To a mineralogist the most interesting occurrence in the Coal measures of South Wales is that of the rare mineral *Millerite*. This is a sulphide of nickel, occurring in the form of delicate brass-like needles or fibres in the fissures of certain clay ironstones, especially in the neighbourhood of Merthyr Tydfil. The mineral is confined to certain courses of ironstone, extending however, over a considerable area, especially the ores known locally as the "Three-quarter Balls," the "Soap Vein," and the "Spotted Vein." In some cases the filaments shoot across the cracks, from wall to wall, whilst in others they are aggregated in divergent tufts. The specimen No. 872 illustrates the behaviour of the mineral. *Millerite* is known sometimes as *nickel pyrites*, whilst its capillary habit has suggested the name of *hair pyrites*.

Nickel is an element which rarely occurs in quantity, though its diffusion seems not to be so limited as was formerly supposed. It has been detected, for example, by Mr. J. Pattinson in the Cleveland ironstone;\* Dr. Pollard found it in a manganese deposit of culm-measure age in Devonshire†; it is known to occur in the manganese nodules of the deep-sea floor; and its presence is recorded by M. A. Jorison, in the dust from chimneys and flues‡ in places where certain Belgian coal has been burnt. The nickel is usually accompanied, even if it occur only in traces, by cobalt; but it may be said generally that nickel is a more abundant element, so that when the nickel and cobalt are associated the former usually dominates. Iron-pyrites is sometimes nickeliferous, and this may represent the

\* *Rep. Brit. Assoc.*, for 1863, p. 49.

† *Summary of Progress, Geol. Surv.*, for 1899, p. 175.

‡ *Ann. Soc. Geol. Belgique*, vol. xxiii. (1895-6), p. 101.

original form in which the nickel was, in many cases, introduced into the rocks. At the same time, it is to be noted that nickel also occurs in basic eruptive rocks, like peridotite, probably in the olivine, whence it may pass, on their alteration, into the resulting serpentine. In many localities nickel-ores occur in a serpentinous matrix.

*Hatchettine* (Nos. 873, 874).

Among the minerals occurring in the contraction-cracks of the ironstone balls of South Wales one of the most remarkable is the substance known as *mineral tallow* or *Hatchettine* (Nos. 873, 874). This is a soft waxy hydrocarbon, often transparent when fresh, and composed of thin yellowish laminae, of rather nacreous lustre, becoming black and opaque on exposure. Scientific attention was first called to it by Rev. J. J. Conybeare, who described it as occurring in fissures in the clay iron-ore, associated with calcite and with small crystals of quartz known as *Merthyr Diamonds*.<sup>\*</sup> It was analysed several years afterwards by Prof. F. W. Johnston.<sup>†</sup> Conybeare named it after Mr. Charles Hatchett, a well-known chemist of the early part of the nineteenth century, who made a special study of bituminous substances.<sup>‡</sup>

A substance described as hatchettine, and therefore if not identical with the mineral of South Wales at least presumably similar to it, has been recorded from certain coal mines in the North of England, and is said to have occurred at one time in such abundance at the South Hetton Pit that the pit boys used it for greasing the axles of their trams§.

MINERALS OF MID-WALES (Nos. 875, 876).

Over a large part of Central Wales there stretches a complicated series of contorted strata, consisting mostly of hard grits and slaty rocks, imperfectly cleaved and generally unfossiliferous, but traversed in many places by mineral veins. These veins are almost exclusively confined, in Cardiganshire, to that part of the Silurian system (Llandovery), distinguished by the late Mr. W. Keating as the *Metalliferous Slate series*.|| No granitic rocks are associated with the slates, and the lodes are not apparently connected with any igneous intrusion. The general course of the veins is E.N.E and W.S.W.,

\* "Description of a new substance found in Ironstone." *Ann. Phil.* [new ser.], vol. i. (1821), p. 136.

† "On the composition of certain mineral substances of organic origin, ii. Hatchettine (*sic*)." *Phil. Mag.*, vol. xii. (1838), p. 338.

‡ Charles Hatchett was born in 1765. Conybeare spelt the name of the mineral *Hatchettine*, but Mr. Hatchett's name ended with a double "t." (*Nat. Dict. Biography*, s. v.) Conybeare withdrew the name in favour of Brande's term, *Mineral Adipocere*.

§ "On Minerals and Salts found in Coal-Pits." By R. Calvert Clapham and John Daglish. *Trans. N. Engl. Inst. Min. Eng.*, vol. xiii., 1864, p. 219.

|| "The Geology of Central Wales." *Quart Journ. Geol. Soc.*, vol. xxxvii. (1881), p. 141. Also: Mr. Herbert Lapworth, *ibid.*, vol. lvi. (1900), p. 67.



but their direction is subject to much local variation, some veins taking quite a zig-zag course, especially changing their direction when the nature of the enclosing rock changes.\*

The infilling of the veins is largely composed of brecciated slaty rock, usually cemented by quartz, with more or less galena and zinc blende. A fine series of brecciated veinstones, including many examples from Mid-Wales, will be found in Wall-cases 31 and 32.

The principal ore is *Galena*, which in some cases is highly argentiferous. Crystals of galena are not uncommon, and contrary to what has been observed in some localities the boldly crystallised ore is often not less rich in silver than the granular galena. *Cerussite* occurs as an alteration-product of the galena, but is not of common occurrence. *Zinc blende* is associated with the lead-ore, sometimes even predominating, but *Calamine* is rare. *Copper-pyrites* often occurs with the galena, though usually in very small quantity. *Iron-pyrites* is found in certain localities in some abundance, but, on the whole, is decidedly rare, and the general absence of pyrites sufficiently explains the fact that the back of the lodes in Mid-Wales is not usually marked by gozzan.

The common spar in the veinstone is *Quartz*, and the experienced miner is in the habit of basing his opinion on the value of a given lode by the character of the quartz. *Calcite* occurs in much smaller quantities, *Barytes* is by no means common, whilst *Fluor-spar* seems to be altogether absent. *Witherite*, or carbonate of barium, has been found locally.

Regularly banded veinstones are rare, and the minerals usually occur in strings and irregular ramifications. Where the veinstone is banded, it has been noted, according to the late Sir W. W. Smyth, that quartz has been first deposited on the vein-wall, and then followed by calcite. In like manner the galena in these ore-deposits seems to have generally preceded the blende.

As an example of argentiferous galena, reference may be made to No. 875, which is a specimen of finely granular ore from the Darren Mine, near Aberystwyth, an ore that yielded an average of 32 ozs. of silver to the ton of lead. It has often been observed that lead-ore is more likely to bear silver when occurring in slate or granite than when in limestone or dolomite.

The lead-veins of Central Wales appear to have tempted the miner at a very early period, as witnessed by the rude stone mauls and dressing stones occasionally found in some of the old workings. It was from the rich silver-lead mines of Cardiganshire that Sir Hugh Myddelton derived the large fortune which he expended, in the early part of the seventeenth century, in his great scheme for supplying London with a source of water by cutting the New River. At a rather later period, the mines of the "Welsh Potosi" were worked

---

\* "On the Mining District of Cardiganshire and Montgomeryshire." By Warrington W. Smyth, M.A. *Mem. Geol. Surv.*, vol. ii., part 2 (1848), p. 655.

by Thomas Bushell, who by authority of Charles I. established a mint at Aberystwyth for coining the bullion obtained from the rich ore of the Welsh mines.\*

At the present time the silver-lead ores of Mid-Wales are subordinate in economic importance to the zinc-ores. In 1902 the mines of Cardiganshire, worked chiefly amid the romantic scenery of the Devil's Bridge, yielded 3,618 tons of zinc-ore, but only 1,314 tons of lead-ore; whilst Montgomeryshire turned out but 275 tons of lead-ore and forty-five tons of zinc-ore. In Carmarthenshire 172 tons of lead were raised.

The Van Mine, near Llanidloes, the only lead mine in Montgomeryshire, was at one time a most productive working. The lode which was worked at this mine, as described by Sir Clement Foster,† ran in a direction E.  $26^{\circ}$  N., and in some places was as much as forty-eight feet in width. Its course could be traced through the slaty country for a distance of nine miles. The lode was in many parts a true breccia, consisting of fragments of slate cemented by galena and zinc blende. The Montgomeryshire lead-ore is represented by No. 876.

#### MINERALS OF NORTH WALES (Nos. 877 to 894).

Whilst certain minerals of North Wales, such as the *brookite* of Tremadoc and the *anglesite* of the Parys Mountain, are of much scientific interest, there are many others which are, or have been, of great industrial importance: such, for instance, are the ores of lead and zinc from the Carboniferous strata of Denbighshire and Flintshire, and the ores of copper, manganese and gold from the older palæozoic rocks of the Principality. A few representatives of both types of mineral are here grouped together.

#### *Lead and Zinc Ores, etc. (No. 877 to 881).*

Roman pigs of lead, with coins, fibulæ and other objects of antiquity, testify to the early date at which the lead-ores of North Wales attracted the explorer. On the disintegration of the lead-veins at their outcrop, masses of ore would be set free and might consequently be found as water-worn lumps in the soil or in the drift; in this way were formed the deposits known as *round ore* or *gravel ore*. Much lead was formerly obtained by driving levels in the drift-gravels, where the ore was generally found resting, by virtue of its destiny, near the bed rock. At the famous Talargoch mine, near Rhyl, the gravel ore was at one time a source of much lead. Similar ore is known in other lead-districts, as in the Mendips. The specimen No. 877 is a rolled pebble of galena from Minera.

---

\* See "Notices of the History of the Lead Mines of Cardiganshire." By Robert Hunt. *Mem. Geol. Surv.*, vol. ii., Part ii. (1848), p. 635. Also: Meyrick's "History and Antiquities of the County of Cardigan." 1810.

† "Notes on the Van Mine," *Trans. Roy. Geol. Soc. Corn.*, vol. x. (1879), p. 33.



At the present time the most productive mines in the Principality are, for lead, the Halkin Mine near Holywell, in Flintshire, and for zinc, the Minera Mine, near Wrexham, in Denbighshire.\* The occurrence of the ore-deposits in the Carboniferous strata of North Wales has been described by Mr. Aubrey Strahan.†

Most of the veins which carry argentiferous galena and blende run approximately in an east and west direction, whilst the cross-courses, or veins which take a north and south course and appear to be generally of later date, contain galena which is much less rich in silver, and they bear no blende, though a little copper pyrites may be present. The ore-bearing veins occur in the middle and upper beds of the Carboniferous Limestone, and in the chert beds of the Millstone Grit. The veins are most productive below certain beds of shale, and Mr. Strahan has suggested that this may be due partly to the shales having acted as "water-tight blankets, checking the flow of underground water," and partly to the decomposition of the pyrites in the shales having evolved sulphuretted hydrogen, which would determine the precipitation of the sulphides of lead and zinc from circulating solutions containing salts of these metals.

The veinstuff in the North Wales ore-deposits may be argillaceous, siliceous or calcareous. *Calcite* is not uncommon, and occurs in some cases in beautiful transparent masses, with rhombohedral cleavage. Pennant, writing in 1796, refers to the Pen-y-bryn Mine, near Holywell, as "remarkable for the quantity of refracting spar, *spatum Islandicum*, of great purity and transparency; and often elegantly infected with marcasite finely disposed in lines."‡ The enclosed mineral may have been copper-pyrites, which occasionally occurs in the form of needle-like crystals, forming bands in the spar.

The specimen No. 881 is an example of the *fluor-spar* sometimes found as a veinstone at the Halkin Mountain. This example is of dark purple colour, and is crystallised in bold interpenetrating cubes. No. 879 shows the *zinc blende* in small, transparent crystals of bright brown colour, whilst No. 880 is an example of *ruby blende*, so called from the beautiful colour, lustre and transparency of the small crystals, which are here associated with dolomite, or pearl spar.

In the shallow parts of the lead-veins and zinc-veins in North Wales, as elsewhere, the metals are often found as carbonates, forming respectively *Cerussite* and *Calamine*. Some of the mines were rich in cerussite, or white lead ore, where the veins passed through rocks which, by their porosity, admitted free circulation of water, bringing the galena under conditions favourable for alteration. No. 878 is a specimen of *Cerussite* from the Jamacia Mine, in

---

\* In 1902 the amount of lead ore raised in Flintshire was 3,977 tons, and in Denbighshire only 234 tons; of this amount Halkin yielded 2,316 tons. In the same year the amount of zinc ore raised in Flintshire was 2,656 tons, and in Denbighshire 3,239 tons, of which Minera yielded 3,218 tons.

† *Mem. Geol. Surv.* "Rhyl, Abergele and Colwyn." Quarter-sheet 79 N.W. (1885); and "Flint, Mold and Ruthin," Quarter-sheet 79 S.E. (1890).

‡ "The History of the Parishes of Whiteford and Holywell," p. 254.

Flintshire. Calamine was at one time so abundant that it was used, in ignorance of its nature, for mending the roads; and when its value came to be recognised, the old roads were picked up for sake of the mineral. Mr. Strahan remarks that calamine is known locally as 'coke,' a word of uncertain origin, and not to be confounded with *cawk*, the common name of barytes.

In the lower beds of the Carboniferous Limestone, which are generally destitute of lead and zinc, iron-ore is not infrequently found in the form of *Hæmatite*. This has probably been formed from the carbonate, which has replaced the limestone as a local substitution product. More notable is the occurrence of nickel and cobalt, discovered in 1870 by Mr. Gage, at the Moel Hiraddug Mine, near Rhyl. These metals occurred in the form of *asbolan*, a black, earthy ore found as grains and lumps in a pocket or irregular cavity in the limestone, containing clay and oxide of iron. The lumps contained in some cases a core of pyrites, which was found to be cobaltiferous and nickeliferous, thus pointing to the probable source of the *asbolan*. The average assay of the black ore yielded 2.05 per cent. of cobalt and 0.75 of nickel. After having been worked for several years, the output ceased in 1890. The occurrence of the mineral has been described by Sir C. Le Neve Foster.\*

#### *Manganese Ores (No. 882).*

*Manganese* occurred in the Flintshire cobalt-ore, and it has also been found as oxide, in other localities in North Wales. The four chemically related metals—iron, nickel, cobalt and manganese—tend to occur in natural association, but in very unequal proportion. Small quantities of nickel and cobalt may, however, be more widely diffused than is generally supposed. Thus, Dr. Pollard found them in a bluish black sand from the Reading beds of Cadmore End Common.†

The specimen No. 882 represents an interesting occurrence of manganese-ore, which is of some commercial importance in Merionethshire and Carnarvonshire. An outcrop of black oxide of manganese was worked many years ago in North Wales, but when followed downwards this gave way to the carbonate, which was considered useless, and the workings were consequently abandoned. Its value, however, came in due time to be recognised, and the ore is now rather largely employed in the production of spiegeleisen and ferro-manganese. In 1902 the amount of manganese ore raised in Merionethshire was 627 tons, and in Carnarvonshire 531 tons. The occurrence of the ore has been described by Sir Clement Foster‡ and by Mr. E. Halse.§

\* "On the Occurrence of Cobalt-ore in Flintshire." *Trans. Roy. Geol. Soc. Corn.*, vol. x., p. 107.

† Summary of Progress for 1900, p. 123.

‡ *Rep. Brit. Assoc.*, Birmingham (1886), p. 655.

§ *Trans. N. Engl. Inst. Min. Eng.*, vol. xxxvi., p. 103. "Note on the Occurrence of Manganese Ores near the Arenigs, Merionethshire." By Edward Halse. *Trans. Fed. Inst. Min. Eng.*, vol. iii., p. 940.



The manganese ore of North Wales occurs as a bedded deposit, of an average thickness of eighteen inches to two feet, intercalated among the Cambrian grits and conglomerates. It is also found locally in pockets and fissures in beds of volcanic ash and porphyry. The ore is mainly a mixture of impure *Dialogite*, or manganese carbonate, with *Rhodonite*, or manganese silicate, and contains from 20 to 32 per cent. of metallic manganese. Near the outcrop it passes rather abruptly into the black oxide, as seen in the specimen here exhibited.

It seems probable that the manganese may have had its source in the volcanic rocks which occur abundantly in North Wales, and whence the manganese may have been leached out by acidulated water and ultimately deposited as the carbonate, or dialogite. The manganese in the well-known concretionary nodules found by the Challenger, on the floor of the deep sea, is supposed to have been derived from basic volcanic rocks. These nodules, of a dull brown colour, formed of successive deposits producing a zonary structure, consist of amorphous hydrated manganese oxides, rather indefinite in composition, and mixed with variable quantities of limonite, clay and other earthy matter.\* They contain not only manganese and iron, but also nickel and cobalt, illustrating the wide distribution and intimate association of these elements.

Manganesiferous incrustations occur on sharks' teeth and bones and on fragments of coral and rock found in deep-sea deposits. A black incrustation consisting largely of manganese oxide is common also on pebbles in river-gravels, and is often deposited by springs. Whilst the carbonates of manganese and iron are isomorphous so that they occur in chemical union in certain crystalline ores, the hydrated oxides of the two metals are usually not crystallised and occur only in a state of mechanical association, more or less distinct.†

The *pisolitic iron-ore* represented by No. 890 is an ore of bluish-black colour, with magnetic properties, occurring as a band at a definite horizon in the Arenig beds of North Wales.

#### *Copper Ores (No. 887).*

*Copper-ores* are rather widely distributed through North and Central Wales, partly in the Carboniferous strata and partly in the older palæozoic rocks, but rarely concentrated in quantity. At the present time the copper produced is but small. In 1902 the Britannia Mine at Snowdon yielded 172 tons; whilst eighty-four tons were raised in Denbighshire, and sixty-five tons in Cardigan-shire. No. 887 is a specimen of copper-pyrites from Snowdon.

The copper-ores of Snowdon, consisting of copper-pyrites in a vein-stone of quartz, were described by the late Sir Andrew Ramsay as occurring in lodes which represent faults.‡ In the early part of the

\* Report of the Challenger, vol. ii., p. 374.

† "The Chemical Relation of Iron and Manganese in Sedimentary Rocks." By R. A. F. Penrose, jr., *Journ. Geology*, vol. i., p. 356.

‡ *Mem. Geol. Survey*, vol. iii. "The Geology of North Wales." By A. C. Ramsay, LL.D., F.R.S., 2nd ed., 1881, p. 158.

last century, small lumps of green carbonate of copper were found in a peat bog near Dolgelly, and led to a remarkable type of copper working. Some Liverpool speculators pared off the turf, burnt it in kilns, and obtained copper from the ashes. The Turf Copper Mine was situated to the west of Dol-y-frwynog; and when the peat was exhausted attention was directed to the neighbouring rocks, which are described as consisting of talcose schists, containing iron-pyrites and copper-pyrites very sparsely scattered in crystals and specks, but in which no distinct copper-lode could be discovered.\* It is probable that waters percolating through the rocks carried off sulphate of copper from the oxidation of the diffused pyrites, and that this solution draining into the bog became reduced by the organic matter. Some branches of oak and birch were found, more or less impregnated with metallic copper.†

Large quantities of copper-ore were formerly obtained from the Parys Mine and the Mona Mine, at Parys Mountain, near Amlwch in Anglesea. The ores consisted of copper-pyrites, iron-pyrites and a complex ore known as *blue stone*, containing the sulphides of lead, zinc and copper, of which a specimen is here exhibited (No. 883). Remains of old workings prove that activity must have prevailed here at a very distant period, and indeed masses of smelted copper, bearing Roman stamps, have been found in the neighbourhood. The Parys Mountain takes its name from Robert Parys, who was Chancellor of North Wales in the reign of Henry IV.‡

Although copper-ore is not directly worked in Anglesea at the present time, considerable quantities of *copper precipitate* are obtained from the cupreous waters which drain through the old workings and the refuse heaps. Scrap iron is introduced into the water, which contains the copper as sulphate, and metallic copper, or *cement copper*, is precipitated; whilst the remaining liquid, containing iron sulphate, yields on exposure to oxidising influences an ochreous deposit, valued as a pigment. In 1902, 450 tons of copper precipitate were obtained from the Parys Mountain, whilst the output of ochre reached the amount of 3,310 tons.

#### *Anglesite* (Nos. 884 to 886).

It is from the Isle of Anglesea that the native sulphate of lead takes its name of *Anglesite*. The mineral appears to have been first recognised as a distinct species by Dr. Withering, who obtained it from the Parys copper mine, where it seems to have occurred at one time in some abundance. Several excellent specimens are here exhibited as Nos. 884 to 886. These show the anglesite in the form of small transparent crystals, belonging to the orthorhombic system, seated on a dull matrix of gozzany limonite. When pure the

\* Ramsay, *Op. cit.*, p. 65.

† *Trans. Geol. Soc.*, 2nd ser., vol. v. (1837), p. 214.

‡ For the geology of Parys Mountain see Ramsay, *Op. cit.* p. 248. Also: *Trans. Manchester Geol. Soc.*, vol. xiv. (1878), p. 357.



crystals are colourless, but they usually present a brownish yellow tint by association with oxide of iron. Like many lead-bearing minerals, anglesite has a peculiar lustre, inclining to adamantine. By the oxidation of the mixed sulphides in the ore above water-level, various sulphates might be produced; and of these sulphates that of lead would be the least soluble, and might therefore be preserved as a crystallised mineral whilst the sulphates of iron, copper and zinc, once associated with it, would be carried off in solution. A certain resistance to common solvents is a necessary condition for the very existence of most minerals.

*Brookite, etc. (Nos. 888 to 893).*

Another interesting mineral from North Wales is *Brookite*, of which some specimens of exceptional beauty are here exhibited as Nos. 888 to 889. Brookite is one of the three species formed by native titanium dioxide, the others being known as anatase and rutile. Lévy distinguished it, in 1825, and named it after Mr. H. J. Brooke, the mineralogist, who was joint author of Brooke and Miller's well-known treatise (*b.* 1771, *d.* 1857).

Brookite, as seen in these specimens, is a hyacinth-red translucent mineral, of almost adamantine lustre, crystallising in the orthorhombic system, and appearing usually in thin crystals of tabular habit, due to predominance of the macropinacoid the planes of which exhibit in many of the specimens well-marked vertical striations.\* The mineral is associated with finely crystallised quartz and with albite. It occurs on the walls of clefts in a quarry of eruptive rock near Fronlon, on the road from Bedgellert to Snowdon. Its occurrence also near Pwllheli has been recorded by Mr. W. J. Harrison, jun.†

Titanium dioxide has been formed artificially by the reaction of titanium fluoride and water-vapour. The process is therefore exactly analogous to that which has yielded cassiterite: indeed, stannic oxide and titanous oxide stand in close chemical relationship. Pneumatolytic action may thus be invoked as a possible explanation of the genesis of brookite. Nor of brookite only: for the other modifications of this trimorphous body,  $TiO_2$ , may, in some cases, have had a like origin. Hautefeuille found that when the reaction between the titanium fluoride and steam was effected at a red heat *Rutile* is formed; at a temperature such as is required for the volatilisation of zinc *Brookite* is produced; and at a temperature just below that at which cadmium may be volatilised *Anatase* results.

It is worth noting that anatase occurs with the brookite of Snowdon. Rutile is found in the cavities of the clay ironstone of Merthyr Tydfil, but there it is probably of quite different origin. It

\* A *pinacoid* is a form consisting of a pair of similar parallel planes, so named from  $\pi\acute{\iota}\nu\alpha\chi$  (*pinax*, a board or slab).

† *Geo. Mag.*, 1894, p. 567.

is well known that rutile, and to a less extent anatase, are widely distributed as microscopic constituents of slates, clays and other sedimentary rocks (see p. 191).

Some of the finest crystals of British *Quartz* are obtained from the neighbourhood of Snowdon. The examples here exhibited (Nos. 891, 892) show that while some of this quartz may be pellucid as rock crystal, other specimens are slightly opalescent and may acquire a certain whiteness and opacity, sufficient to justify their suggestive name of *milky quartz*.

No. 893 is a specimen of the well-known *Jasper* of Carnarvonshire, which has occasionally been worked as an ornamental stone.

In the Horse-shoe Case will be found some fine examples of *Asbestos*, or fibrous hornblende, a mineral which occurs as veins in the rocks of Moel Hebog, near Snowdon, and has been used industrially.

#### *Welsh Gold (No. 894).*

Mention has already been made (p. 18) in connection with the Cornish tin-ore of the wide distribution in minute quantity of *Native Gold*. Scattered more or less sparingly through the quartz-veins in many parts of Wales, the metal is set free on the disintegration of these veins at their outcrop, and by its density tends to accumulate in local depressions, after the associated quartz has been swept away by running water. Keltic tradition, not unsupported by archæological discovery, points to the rather profuse use of Welsh gold at a very remote period.\* Nor is this unreasonable. The early settlers in the country might no doubt find much gold in the alluvial deposits, not necessarily because the auriferous veins were then richer than they now are, but rather because the materials of these veins had been subjected during long periods of time to natural processes of washing and dressing, so that the produce of ages might be found in a concentrated form.

If alluvial gold satisfied the wants of the prehistoric inhabitant of what is now Wales, the Roman invader was bold enough to attack the obdurate reef itself. Remains of workings, reputed on high authority to be Roman, still exist at Gogofau, near Lampeter, in Carmarthenshire, showing that gold was extracted with much labour from the quartz-lodes. Iron-pyrites is the principal metallic mineral, but free gold was detected by the Geological Surveyors.†

In modern times, much attention has been directed to the gold-bearing rocks of Merionethshire, where veins of quartz, occasionally with calcite, carry iron-pyrites, copper-pyrites, zinc-blende and galena, associated with more or less gold. According to Sir A. C. Ramsay, the lodes run through the Lingula flags and Cambrian grits, especially in the neighbourhood of intrusive rocks, and in association

---

\* See, for instance, an "Historical Account or an Inquiry into the Situation of the Gold Mines of the Ancient Britons." *Cambrian Register*, vol. iii., p. 31.

† Notes on the Gogofau, or Ogo-fau, Mine, near Pumpsant, Carmarthenshire." By Warington W. Smyth, M.A. *Mem. Geol. Surv.*, vol. i. (1846), p. 480.



with certain rocks of talcose character.\* Sir W. W. Smyth pointed out the interesting fact that the gold is accompanied by tetradymite, or telluric bismuth—a mineral which occurs in companionship with gold at several other localities.† Many illustrations of the occurrence of Welsh gold will be found in Wall-case 14.

Attention was called in 1843 by the late Mr. Arthur Dean to his discovery of gold at Cwm Eisen, a mine which had been previously worked for lead.‡ This announcement led to extended search, resulting in the detection of gold over a wide district, notably between Dolgelly and Barmouth, and in the alluvial deposits in the valley of the Mawddach. Operations were carried on at several mines, some of which, like the Vigra and Clogau, were on lodes previously worked for copper. These workings, however, were conducted for many years on a comparatively small scale, and were only intermittently productive until Mr. Pritchard Morgan, returning to Wales with a knowledge of gold mining acquired in Australia, undertook operations of a bold character at Gwynfynydd. At the present time gold mining is carried on at St. David's mine, formerly the Clogau, near Dolgelly; at Gwyn, formerly the British Goldfields, Gwynfynydd; at Ffridd Goch, Dolgelly; and at Cefn Goch, Tynygroes. According to the official statistics, these workings yielded during the year 1902 a total quantity of 29,953 tons of gold ore, of the estimated value of £12,621. The amount of gold extracted from this ore was 4,181 ozs., and its value £14,570. These returns show a serious decline in the output. Thus, in 1900 the amount of Welsh gold obtained during the year was valued at £52,147.§

Analyses by the late Mr. David Forbes showed that a specimen of gold from the Clogau lode contained upwards of 9 per cent. of silver, the native metal thus corresponding to an alloy of the composition  $Au_6Ag$ ; whilst a sample of stream gold from the Mawddach yielded as much as 18.99 per cent. of silver.|| When the proportion of silver in native gold reaches 20 per cent., the alloy is called *Electrum*. The association of the Welsh gold with iron-pyrites and in some cases with brown ochreous oxide of iron resulting from the alteration of the sulphide, suggests that here, as in so many other localities, the precious metal may have been originally brought up, from a plutonic source, with the pyrites and set free on its decomposition.

\* "On the Geology of the Gold-bearing district of Merionethshire, North Wales." By Prof. A. C. Ramsay. *Quart. Jour. Geol. Soc.*, vol. x. (1854), p. 242. Also *Geol. Surv. Mem.* "Geology of North Wales," p. 59.

† "Gold Mining at Clogau, North Wales." *Mining and Smelting Mag.*, vol. i. (1866), p. 359.

‡ *Rept. Brit. Assoc.* York (1844), p. 56.

§ "Mines and Quarries: General Report and Statistics for 1902." Edited by C. Le Neve Foster, D.Sc., F.R.S. (1903), p. 210.

|| "Researches in British Mineralogy." *Phil. Mag.* (1867), p. 329.

## DIVISION 2.

## MINERALS OF DERBYSHIRE.

## THE SPARS

(Nos. 895 to 962.)

Metal-mining in Derbyshire, though now declining in importance, is a very ancient industry, which was directed originally to the extraction of the ores of lead, and subsequently to those of lead and zinc. The ores—consisting of the normal sulphides, galena and blende, with their alteration-products—are associated in the ore-deposits of Derbyshire with calcite, fluor-spar and barytes. Three types of ore repositories are recognised—the rakes, the pipes and the flats. These seem to represent fissures, varying in magnitude and direction, in the Carboniferous Limestone, which forms the characteristic rock in the mining districts of the county. Channels for the passage of water through the limestone are formed by the planes of jointing, bedding, and faulting; and the solvent action of the circulating liquid produces irregular cavities which may become receptacles for ore. It is probable, too, that here as in many other limestone districts, the ore may, in some cases, have been substituted for the calcareous rock by a process of molecular replacement. The ore-deposits are said to be most numerous and most productive in the upper part of the limestone, some of the richest bodies of ore having been found immediately under the Yoredale shales.\*

Interstratified with the limestones there are occasional sheets of basic eruptive rocks, usually olivine-dolerites, known locally as *toadstone*, and in many cases representing contemporaneous lava flows.† The old belief that the mineral-veins disappear in the toadstone has often been disproved, though it remains a fact—subject, however, to occasional exception—that the veins tend to become thinner and to suffer impoverishment when they pass into the igneous rock. It is generally held that the toadstone owes its name to its barren character, the word being a corruption of *Todtstein*, or “deadstone.” German miners, or as old writers sometimes call them, “Dutch mineral men,” were occasionally brought over to this country for the sake of their expert knowledge, and it is not unlikely that they should apply such a name to a rock in which the ore died out.

The *Rakes*, or *Rake veins*, of the Derbyshire mines are deposits in fissures representing joints in the limestone, more or less vertical in direction, and sometimes corresponding with faults. The ore occurs

---

\* On the Geology of the district and on the Occurrence of the Ores, see *Mem. Geol. Surv.* “North Derbyshire.” By A. H. Green, C. Le Neve Foster, and J. R. Dakyns. 2nd Ed. (1887). By A. H. Green and A. Strahan.

† See “The Ancient Volcanoes of Great Britain.” By Sir Archibald Geikie, F.R.S. (1897), vol. ii., p. 8. And important papers by Mr. H. H. Arnold-Bemrose in *Quart. Journ. Geol. Soc.*, vol. l. (1894), p. 603; vol. lv. (1899), pp. 224, 239.



either in parallel ribs, alternating with bands of veinstuff, or in isolated masses scattered through the sparry matrix. The term *scrin* is applied to a string, or small rake; and in some cases a mass of limestone may be traversed by a network of these veinlets, consisting of galena.

Much of the lead-ore occurs, however, in the so-called *Pipes*, or *pipe veins*, which are deposits in cavities widened by erosion in the inclined direction of the beds of limestone, and connected one with another by means of leaders running along joints. Another mode of occurrence is that of *Flats* or *flat veins*, a name given to irregular sheet-like masses of ore disposed along the planes of bedding.

It is found convenient to exhibit the metallic minerals in the following Case, No. VIII., so that the series in Case VII., now under notice, is limited to the three sparry minerals which form the principal veinstuff of the Derbyshire deposits—namely *calc spar*, or calcite, *fluor-spar*, or fluorite, and *heavy spar*, or barytes.

#### *Calcite* (Nos. 895 to 938).

Where ore-deposits occur in limestone, like those of Derbyshire, *Calcite* is likely to be a common mineral, crystallising in any free cavity, whether in the veinstone or in the neighbouring rock. Some of the finest known crystals of this species have been brought to light from the lead-mines of Derbyshire. A rather extensive series of specimens is here exhibited, sufficient to give some notion of their beauty and variety of form, but the specimens are necessarily of small size, and the visitor should consequently turn to the Horse-shoe Case (Section I.) in order to realise the magnitude attained by some of the Derbyshire crystals, especially the large yellowish scalenohedra.

Calcite presents an unparalleled wealth of crystalline forms. The most characteristic of the Derbyshire crystals have a scalenohedral habit, and are known from their sharp-pointed extremities as *Dog-tooth spar* (Nos. 895 to 906). The scalenohedron is a solid bounded by twelve scalene triangles, and having the lateral edges rising and falling in a zig-zag manner, like those of a rhombohedron. Other crystals assume a prismatic habit, the six-sided prism being often terminated by the faces of a rhombohedron or of a scalenohedron (Nos. 907 to 910). In some cases, as in No. 911, the crystals are very complex, being highly charged with faces. Twin crystals are of frequent occurrence. It is not uncommon in Derbyshire specimens to find scalenohedral crystals having re-entrant angles, producing notches in the equatorial belt, showing that the scalenohedron is twinned on the basal pinacoid (No. 897). But the most interesting twinned crystals are those found many years ago at Eyam and known as *butterfly twins* (No. 917). These are in some cases quite heart-shaped, constituting the type which de Bournon called "*la charmante macle*"—"chaux carbonatée en cœur." \* They are scalenohedra twinned on a plane

---

\* "*Traité de Minéralogie*," vol. ii. (1808), p. 66.

of the rhombohedron. The Eyam twins are rather rare in collections, but similar crystals of larger size have been discovered in recent years in the hæmatite mines of the North (p 149), and are comparatively common.

Whatever the form assumed by calcite, the crystal always offers perfect rhombohedral cleavage. No. 912 is a cleavage rhombohedron; but this fundamental form is rarely assumed independently by British calcite, or for the matter of that, by any calcite, except that from Iceland. The cleaved specimen No. 912 presents a delicate yellow colour, due probably to the presence of iron. In the columnar crystalline specimen No. 932 the yellowish colour is very pronounced, giving the substance the tint of sugar candy. Most of the Derbyshire calcite, however, is colourless or dead white. The opaque white spar from some of the mineral-veins in Derbyshire is crushed, and employed for making paths.\*

Cavities in the fossils of the carboniferous limestone are sometimes lined with beautiful crystals of calcite. No. 933, for example, is a Derbyshire specimen, showing a crop of such crystals, studding the inner shell-wall of the valve of a *Productus*. Another example is furnished by No. 934.

The specimen of *stalagmite*, or *dripstone*, No. 935, illustrates the formation of a calcareous deposit, in layers, from solution in water. Meteoric waters, charged with carbonic acid, filter through the limestone and drain along the planes of jointing and bedding, dissolving the rock by forming a soluble acid calcium carbonate, or bi-carbonate of lime. The loosely associated carbonic acid is readily eliminated from this compound, by elevation of temperature, or by exposure to air, or by the action of living vegetation, and the calcareous salt is thereby reduced to the condition of the normal or neutral carbonate, which is but very sparingly soluble in water, so that it is easily precipitated. In recent years much attention has been given to organic action in determining the deposition of calcareous matter; and the researches of Dr. Cohn, Mr. W. H. Weed† and others tend to show that algaous growths and other forms of plant life are frequently instrumental in causing precipitation, even in the calcareous sinter of hot springs. No. 937 is a specimen of *tufa* encrusting *Chara*, deposited by the calcareous waters of Matlock in Derbyshire. It should be added that organic acids, derived mainly from decomposing vegetable matter, greatly assist in the solution of limestone-rocks.

Some of the coral-like deposits of carbonate of lime, like No. 938, consist of *Aragonite*. It is generally held that the temperature at which deposition occurs is an important factor in determining whether the deposit shall take the form of calcite, or of the harder and denser aragonite. This subject will be again referred to (p. 150).

---

\* *Mem. Geol. Surv.*, North Derbyshire (1887), p. 163.

† "Formation of Travertine and Siliceous Sinter by the Vegetation of Hot Springs." By Walter Harvey Weed. *Ninth Ann. Rep. U.S. Geol. Surv.* (1889), p. 613.



Dr. G. P. Merrill has shown that many stalagmitic deposits commonly regarded as aragonite really consist of carbonate of lime in the normal form of calcite.\*

*Elaterite, etc. (Nos. 939 to 942).*

The curious soft substance represented by No. 939 is known as *Elaterite*, *elastic bitumen* or *mineral caoutchouc*—names which are sufficiently suggestive of its characters. It appears to have been first noticed about the year 1786 at the Odin Mine, near Castleton, one of the oldest mines in the country. Scientific attention was not called to it, however, until 1797, when Mr. C. Hatchett, who had made a special study of bituminous minerals, described it as a new species of bitumen, much resembling in elasticity and colour “the substance known by the name of caoutchou (*sic*), or india-rubber.”† According to Prof. J. W. F. Johnston, who analysed three specimens from Derbyshire, the origin of the substance is probably attributable to the effect of heat exerted by igneous rocks on the organic matter of the Carboniferous Limestone, whereby volatile products were evolved and condensed in the cooler rocks.‡ The substance has also been found near Windy Knoll.

In the specimens Nos. 941, 942, hard brittle bitumen, or *asphalt*, is seen occurring in the form of small globular masses, with dog-tooth calcite, and blende, on fluor limestone. The form of this asphalt suggests that it represents solidified drops of a substance once liquid. Petroleum, or rock oil, sometimes oozes from the rocks, and explosive gases have often occurred in the lead mines.§

Such bituminous substances, representing probably the organic matter of the Carboniferous rocks, invite the suggestion that they, or kindred substances, may have played some part in the process of ore-formation by acting as reducing agents, and thus determining the formation of metallic sulphides, like galena, blende and pyrites, from solutions of the sulphates. The importance of bituminous substances, and even of the small proportion of organic matter in limestone, as reducing agents in the formation of ore-deposits, has been recently insisted on by Dr. W. P. Jenny.||

*Fluorite (Nos. 943 to 954).*

In connection with the fine specimens of *Fluorspar*, or *fluorite*, from the West of England mines, exhibited in Case V. (p. 85), so much has already been said about this species that the Derbyshire

\* “The Onyx Marbles.” By George P. Merrill. *Rep. U.S. Nat. Mus.* for 1893 (1895), p. 539.

† “Observations on Bituminous Substances, With a Description of the Varieties of the Elastic Bitumen.” *Trans. Linn. Soc.*, vol. iv. (1797), p. 129.

‡ “On the Composition of Certain Mineral Substances of Organic Origin. V., Elastic Bitumen of Derbyshire.” *Phil. Mag.*, vol. iii. (1838), p. 22.

§ *Geol. Surv. Mem.*, North Derbyshire, p. 164.

|| “The Chemistry of Ore-deposition.” *Trans. Am. Inst. Min. Eng.*, vol. xxxiii. (1903), p. 445.

specimens displayed in this part of the Collection call for little remark. The spar occurs in many of the lead-mines as a gangue-mineral, or constituent of the vein-stuff, and is raised to a limited extent for use as a fluxing agent in metallurgical operations (whence indeed its original name, from *fluo*, to flow). It is also employed in the manufacture of a milky glass, in the production of hydrofluoric acid for etching glass, and as a source of various fluorine-compounds for laboratory use; nor must its value as an ornamental stone be forgotten. In the year 1902 1,297 tons of the spar, valued at £1,584, were raised in Derbyshire.

Of all kinds of Derbyshire spar the most beautiful is the purple fluor known as "Blue John," a name apparently correlative with "Black Jack," the miners' common name for zinc-blende. The specimens here shown illustrate the colour and structure of this spar (Nos. 953, 954). It is found almost exclusively near Castleton at the famous "Blue John Mine," situated on the side of Tray Cliff, in the midst of the wild scenery of the Peak. It is generally found in nodular masses, with a fibrous and concentric structure, enveloped in a clayey matrix occupying a fissure or pipe. The clay may represent the insoluble residue left by removal of the limestone in solution.\*

The dark brownish purple fluor is called by the workmen "bull beef," but the colour is greatly altered, and a beautiful amethystine tint produced, by exposure to heat or by other artificial treatment. Where the spar crops out in the rocks, the "changing" is effected by the natural heat of the sun, and the dark blue fluor acquires a purple colour. The spar at the Blue John Mine was first found by two miners named John Kirk and Joseph Hall; and its use for ornamental purposes dates from about 1770, when it was introduced by Mr. Robert Hall, of Castleton.†

Many specimens of polished fluor from Derbyshire, including some fine vases, will be found in the Hall of the Museum. The grand amphora on a pedestal at the northern end of the Principal Floor (No. 27), presented by the late S. Addington, Esq., is believed to be the largest specimen of its kind in existence, measuring as it does as much as two feet eight inches in height. It was the work of Mr. Vallance, of Matlock.

### *Barytes* (Nos. 956 to 960).

Sulphate of barium, forming the mineral known as *Barytes*, is very common as a matrix of galena in lead-veins which traverse limestone. Although it occurs as a gangue-mineral in Derbyshire it is rarely crystallised, and as far finer specimens are exhibited from the North, especially from Cumberland, any detailed notice of the species may be suitably deferred (*see* p. 168).

---

\* *Geol. Surv. Mem.*, North Derbyshire, p. 162, where a figure illustrates the occurrence of the Blue John.

† "Gem of the Peak: Part V., History of the Fluorspar, Ancient and Modern." By W. Adams. 4th Ed., 1845.



Barytes is extensively used as a white pigment, and in 1902 Derbyshire yielded 334 tons of the mineral. This consists principally of the white earthy barytes known as *cawk* or *caulk*.

Some notable varieties of barytes occur in Derbyshire. A white arborescent barytes, with brown earthy oxide of iron, formerly found at Bonsal Moor, was known from its form as *brainstone*. No. 959 is a curious black variety of barytes, containing, according to an analysis by Prof. G. A. Kcenig, 3.1 per cent. of oxide of manganese.\* The remarkable *stalactitic barytes*, found in every mineral collection, is illustrated by Nos. 956 to 958. This variety was first found in 1832, embedded in clay in a cross course on Arbellow, at Middleton, near Youlgreave. Transverse sections exhibit a beautiful radiated structure, with well-marked concentric rings, suggestive of the section of an exogenous tree stem; and this structure, coupled with the rich brown colour, has led to its being popularly called "fossil oak." The zonal pattern displayed in section has also led to the rather unfortunate name of "onyx stone." It is used to a limited extent when cut and polished, as an ornamental stone, especially as a material in inlaid marble work.

*Quartz* (Nos. 961, 962).

Quartz is by no means common among the minerals of Derbyshire.† But in the neighbourhood of Buxton there are small crystals of quartz, generally found loose in the soil, and known as *Buxton Diamonds*. As seen in No. 961, the crystals present the form of hexagonal prisms, terminated usually at each end by a hexagonal pyramid. Whilst some are perfectly colourless, others are tinted brown, with oxide of iron. They appear to have been derived from such a source as is represented by No. 962, a specimen which shows similar doubly-terminated crystals in a matrix of flesh-coloured barytes.

---

\* *Proc. Acad. Nat. Sc. Phil.* for 1878 (1879). p. 99.

† On quartz, see paper "On the Super-position of Quartz Crystals on Calcite in the Igneous Rocks occurring in the Carboniferous Limestone of Derbyshire." By W. F. Holroyd and J. Barnes. *Trans. Manch. Geol. Soc.*, vol. xxvi. (1901), p. 46.

## CASE VIII.

## DIVISION 1.

## MINERALS OF DERBYSHIRE.

## THE ORES.

*Galena* (Nos. 963 to 986).

In this division of the Collection there is a fair display of the ores of Derbyshire, chiefly those of lead and zinc. Some of the lead-mines have yielded crystals of *Galena* exceptional in magnitude and beauty. Thus, the Mill Close Mine, in Darley Dale, at present the most productive mine in Derbyshire, has furnished cubes of galena measuring two inches along the edge, with dog-tooth spar measuring a foot along the vertical axis of the scalenohedron.\* The occurrence of fine crystals lining hollows in the veinstone, or studding the walls and roof of fissures in the limestone, suggests the deposition of galena in free cavities; though its formation by molecular replacement of a calcareous rock is also to be frequently recognised where ores of lead and zinc occur in limestone (p. 164).

The crystals of Derbyshire galena here exhibited show the mineral in cubes and octahedra, but mostly in combinations of the two forms, or cubo-octahedra. Some of the specimens present the characteristic cubic cleavage, and in No. 971 the cleavage face is marked diagonally by striations due to twin lamellæ. The very brilliant metallic lustre of galena, which has led to its being called "the diamond among ores," is well displayed by such specimens as No. 972; but the lustre is usually lost on exposure, and in some cases the tarnish is brilliantly iridescent, as in Nos. 968, 969. Galena, in consequence of its lustre, is sometimes known as *Lead glance*.

The coarsely-crystalline galena, generally considered, though sometimes erroneously, to be poor in silver, is known from its use in glazing pottery as *potters' ore*.† The amount of lead ore, principally galena, raised in Derbyshire in 1902 was 3,555 tons.

\* "The Deposit at the Mill Close Lead Mine, Darley Dale, Matlock." By Cyril E. Parsons. *Trans. Fed. Inst.*, vol. xii. (1896), p. 115.

† On the Continent this ore is known as *alquifour*—a word which is derived, as Prof. Bauerman has pointed out, from the Italian *archifoglio*, or "large-leaved," being the name applied to it in the Levant trade. The ore is exported to Egypt as a remedy in ophthalmia and for painting the eyelids. The Arab name is *kohlhe*, whence it is known in parts of Spain, where it is used in potteries, as *alcohol*. "The Metallurgy of Lead." By John Percy, M.D., F.R.S., 1870, p. 94.



In the specimen No. 982, the smooth surface of the galena presents a natural polish, and is known as a *slickenside*. This polish is the result of friction due to movement in the vein, and the direction of movement is indicated by the grooving or fluting seen on the face of the stone. It is remarkable that some of the Derbyshire slickensides, on being struck with a pick, will explode with more or less violence. The molecules of the rock appear to be in a condition of severe strain, like those of a Rupert's drop, so that the slightest breach of continuity at one spot, such as may be produced by a mere scratch, will disturb the unstable equilibrium and lead to disruption throughout a considerable mass. The subject of explosive slickensides has been studied by Mr. A. Strahan.\*

Many of the specimens in this case illustrate the characteristic associates of galena. In No. 983 the galena occurs with calcite; in No. 984 with fluorite; in No. 985 with barytes; and in No. 986 with blende. The occurrence of galena with the minerals resulting from its own alteration, like cerussite and anglesite, is illustrated in the following series.

*Cerussite (Nos. 987 to 990).*

The formation of *Cerussite*, or carbonate of lead, from galena is illustrated by several specimens in this Case (Nos. 987 to 989), where the two minerals are intimately associated, whilst the galena shows in some cases, by its eroded surface, that it has suffered much alteration. Frequently the carbonate occurs as a white, earthy incrustation on the weathered galena near the back of a vein. Regarded formerly, according to Farey, as a useless spar, it was either left in the mines or thrown away and buried in the hillocks. At times it has been rather extensively worked under the name of *white ore* or *wheat stone*, and a vein at Tideswell Moor has received the name of the "White Rake," in consequence of the occurrence of this mineral.

The direct oxidation of galena might be expected to give rise to anglesite rather than to cerussite, since the sulphide would become converted into sulphate; but the reaction of this sulphate with the limestone would result in the formation of a carbonate. The action of carbonated waters on galena in a limestone matrix invariably produces cerussite; and hence masses of galena, more or less altered to impure white ore, or 'lead earth' (*Bleierde*), are often found in ore-deposits, within reach of surface drainage.

The fine prismatic crystal of cerussite, numbered 990, is dull and blackened on the surface. Such discolouration is probably due to the formation of a thin layer of black sulphide, consequent on attack by sulphuretted hydrogen. This product is often evolved from decomposing sulphides. Moreover, the sulphur compounds emitted by blasting operations in mines tend to blacken any white lead-ore in their neighbourhood.

---

\* "On Explosive Slickensides." *Geol. Mag.*, Dec. 3, vol. iv. (1887), p. 460.

*Anglesite, etc. (Nos. 991 to 994).*

Wherever galena has suffered oxidation, but has been shielded from the attack of carbonates, *Anglesite*, or sulphate of lead, may be expected to occur. Although in limestone districts it is naturally not so common as cerussite, fine crystals have occasionally been yielded by the lead mines of Derbyshire. Of these, several examples are here shown (Nos. 991 to 993). The characters of the species have already been described in connection with the original occurrence in Anglesea (p. 127).

It is worth noting that although galena and blende occur together in the Derbyshire mines, the products of their oxidation present marked differences. Sulphate of lead is very sparingly soluble in water whilst sulphate of zinc is freely soluble. Hence the lead compound remains as a fairly stable mineral, whilst the zinc salt is carried off in solution and is rarely found in a solid form. *Goslarite*, or sulphate of zinc, though not unknown in stalactitic forms in certain mines, may be practically ignored as a British species.

Specimens of lead-ore from the refuse-heaps of an old mine near Brassington were collected by Sir H. T. de la Beche, to illustrate the alteration of galena by prolonged weathering, and were described in his *Geological Observer* (p. 692). Several of these specimens are exhibited in Wall-case No. 35. They show the galena encrusted with cerussite and pyromorphite—that is to say, the sulphide has been more or less completely converted into carbonate and phosphate. The brown phosphate is known as *linnets*, and the green as *green linnets*. No. 994 is an example of these alteration-products from the Brassington hillocks. The name of “Green Linnets” was given to the mine which yielded these specimens.

*Matlockite and Phosgenite or Cromfordite (Nos. 995 to 1006).*

Derbyshire has contributed to the group of plumbiferous minerals two rare and interesting species, which have been called, from their original localities, *Matlockite* and *Cromfordite*. Both minerals contain lead in the form of chloride, associated in the former with an oxide, and in the latter with a carbonate of lead. Such at least is the common interpretation of their constitution. Again, both crystallise in the tetragonal system; but whilst the crystals of matlockite usually have a tabular habit, due to development of the basal pinacoid, those of cromfordite, though sometimes tabular, have generally a prismatic habit.

With regard to the names of these two species it may be remarked that whilst matlockite is the name universally used to designate the oxychloride, the term cromfordite, proposed by Greg and Lettsom for the oxycarbonate, and locally appropriate, has given place, in most quarters, to Breithaupt's name *Phosgenite*,\* which, notwithstanding its rather fanciful origin, has survived by right of priority.

---

\* *Phil. Mag.*, ser. 4, vol. ii. (1851), p. 120.



The fine series of specimens of matlockite, Nos. 995 to 1002, illustrate the typical characters of this mineral, showing the yellowish adamantine tabular crystals, in some cases slightly curved and aggregated in groups with a tendency to a globular form. The mineral is identical in chemical composition with the white pigment at one time largely prepared under the name of Pattinson's oxychloride of lead.\* Matlockite has been found among the sublimation products of Vesuvius; but its occurrence in Derbyshire suggests, of course, quite a different origin, and rather recalls the mode of formation of mendipite—another oxychloride of lead already noticed in connection with the minerals of Somersetshire. The relation of matlockite and mendipite is seen by comparison of their formulæ :

Matlockite	...	...	...	Pb Cl <sub>2</sub> .	PbO.
Mendipite	...	...	...	Pb Cl <sub>2</sub> .	(PbO) <sub>2</sub> .

Phosgenite is represented by a fine suite of specimens (Nos. 1003 to 1006), including some beautiful transparent crystals, faintly yellowish in colour and adamantine in lustre. The formula of the species may be written Pb Cl<sub>2</sub>. Pb CO<sub>3</sub>. It has been found naturally altered to Cerussite, a change obviously brought about by removal of the molecule of lead chloride. Phosgenite has been found in the neogenic deposits of Bourbonne-les-Bains, and in the old slags of Laurion, where the chlorine has been supplied by the sea-water.

Soluble chlorides reacting with carbonate of lead, dissolved by carbonic acid, might give rise to such a chloro-carbonate as phosgenite. The artificial production of this species was effected by MM. Friedel and Sarasin, by heating a mixture of chloride and carbonate of lead with water in a closed tube at a temperature of 180°. With regard, however, to the Derbyshire mineral, which was produced by the alteration of galena, there is no reason to suggest for its production an elevated temperature. It is therefore interesting to note that M. A. de Schulten has effected the synthesis of crystallised phosgenite at ordinary temperature by passing a current of carbonic acid gas through an aqueous solution of chloride of lead.†

Both matlockite and phosgenite were originally found in old workings in the lead mines near Cromford, not far from Matlock. The locality given for phosgenite was the Boge Mine, in the little village of Bole Hill. The chlorine in these minerals may possibly have been derived, as suggested with regard to mendipite (p. 109), either from neighbouring saliferous rocks now removed or more probably from surface-waters carrying a small proportion of chlorides.

#### *Blende (Nos. 1007 to 1010).*

In Derbyshire, as in so many other localities in limestone rocks, the ores of zinc occur in intimate association with those of lead.

\* Percy's "Metallurgy of Lead." 1870, pp. 79, 81.

† "Sur la production artificielle à la température ordinaire de la Phosgénite." Par M. A. de Schulten. *Bull. Soc. Fr. Min.*, vol. xx. (1897), p. 191

The principal zinc-ores are the sulphide and the carbonate, the latter being in most cases a secondary mineral derived from the former.

Whilst the native sulphide is commonly known as *zinc blende*, or simply *blende*, it is nowadays frequently termed by mineralogists *sphalerite*—a name due to Haidinger, who, in the year 1845, introduced it as a scientific word having much the same meaning as the vulgar name “*blende*”;\* that is to say, it indicated the deceptive character of the mineral which had led to its occasional confusion with *galena*. The same idea is conveyed by the miners’ terms *mock ore*, *false lead*, or *black Jack*.

In deposits of mixed lead and zinc-ores the lead is likely to occur in the upper part and the zinc below; and for this and other reasons the working of zinc-ore in a given district is often of comparatively recent date. *Blende* is less stable than *galena*, so that in the zone of oxidation it will be first attacked; and moreover, the zinc sulphate by reason of its greater solubility is so much more mobile than the lead sulphate that it will tend to move downwards, where it may be reduced to a less soluble form.

Some of the specimens show the *blende* in association with cubes of *fluorspar* (as No. 1008); and in specimen (No. 1009) it is crystallised with *fluor* in a fossil shell. The dark colour of common *blende*, whence the name “*black*” *Jack*, is due to iron, probably in the condition of *FeS*, a compound which occurs as a cubic mineral in meteorites, and is known as *Troilite*. The ‘*rosin blende*’ is paler.

At the present time the only mine in Derbyshire raising zinc-ore is the Mill Close Mine, in Darley Dale, which yielded 538 tons of ore in 1902.

#### *Calamine, etc. (Nos. 1011 to 1018).*

Solutions containing zinc, such as those resulting from the alteration of *blende*, are apt, on percolation through limestone, to form carbonate of zinc, or *calamine*; and since this body, unlike its isomorph, ferrous carbonate, is characterised by much stability, the metal may remain fixed in the form of carbonate.

Zinciferous solutions, by slowly attacking limestone, may effect the gradual substitution of zinc for calcium, and thus give rise to metasomatic deposits of *calamine*. In No. 1012 crystals of Derbyshire dog-tooth spar have suffered partial alteration, and show a thin external crust of *calamine*. The same kind of crustal alteration has roughly affected the two bold scalenohedra in No. 1013. The next specimen, No. 1014, shows that the *calcite* has been partially dissolved away beneath the *calamine*, so that a thin shell of the zinc carbonate is separated by a solution-space from a nucleus of unaltered *calcite*. In No. 1015 all the *calcite* has disappeared, leaving nothing but a thin shell of *calamine* representing not only the

---

\* *Sphalerite* from *σφαλερός* (*sphaleros*) deceptive; *Blende* from Ger. *blenden*, to dazzle or to blind.



external form of the scalenohedral calcite but even the direction of the cleavage-planes along which the calamine has penetrated. Pseudomorphs of calamine after dog-tooth spar have attracted the attention of observers from the days of Pilkington, more than a century ago.\*

With regard to the origin of calamine, it has been objected that the reaction of carbonate of lime on a solution of sulphate of zinc tends to precipitate the zinc as a hydrocarbonate. It is true that the anhydrous zinc carbonate is not thrown down in laboratory reactions, but M. Lodin has argued that under natural conditions there are various ways in which the anhydrous salt might be precipitated, especially by the presence of an excess of carbonate of lime, such as exists in a limestone district.†

The series of Derbyshire minerals is brought to a close by some specimens of *pyrite* and *marcasite* (Nos. 1019 to 1022), which scarcely call for special remark. The *marcasite* in No. 1021 shews the form called "spear-head pyrites," and in No. 1022 that known as "cock's-comb pyrites," the mineral in both specimens having suffered epigenic alteration to limonite.

#### MINERALS FROM ECTON.

(Nos. 1023 to 1030.)

A few specimens from the famous copper-mine of Ecton are here exhibited, for though Ecton is topographically within the borders of Staffordshire, it is closely related geologically to the adjacent part of Derbyshire. It is known that this mine was worked by German miners brought over by Prince Rupert in the seventeenth century, and that they introduced into this country the practice of blasting. At one time the Ecton mine was described as "perhaps the richest copper mine in Europe."‡

According to Dr. Watson, writing in 1860,§ the ores occurred in veins and saddles. The copper-ore was mostly found in the saddles, the mineral occurring in the arches of sharply folded Carboniferous Limestone, whilst the pipe-veins and rake-veins usually carried galena with a small quantity of blende. Mr. W. Bowman, the manager of the Ecton Company, which started fresh workings in 1883, describes the mine as essentially a "pipe work."|| As a rule, galena was found in the higher levels and copper-ore

\* *Geol. Surv. Mem.*, "North Derbyshire," p. 127.

† "Note sur l'origine des gîtes calaminaires." Par A. Lodin. *Bull. Soc. Geol. Fr.*, ser. 3, vol. xix. (1891), p. 783.

‡ For a description of the mine see the *Geol. Surv. Mem.* on "North Derbyshire," p. 156.

§ "Notes on the Metalliferous Saddles, or ore-bearing beds in the contorted strata of the Lower Carboniferous rocks of certain parts of Derbyshire and North Staffordshire." By Dr. Joseph J. W. Watson. *The Geologist*, vol. iii. (1860), p. 357.

|| North Derbyshire Memoir, p. 157.

in the lower. The copper-ore was chiefly chalcopyrite, associated, however, with erubescite, and with such alteration-products as malachite. Calcite formed the ordinary vein-stuff, but barytes and fluorspar also occurred in the deposits.

Occasionally a pipe, incompletely filled with ore, would have the walls of the cavity studded with fine crystals of calcite. Some of these were large scalenohedra, enveloping crystals of copper-pyrites, which could be seen through the translucent body of the crystal. Such a specimen is shown here (No. 1028), and some larger examples will be found in the Wall-case 28. No. 1029 is a specimen showing barytes, or cawk, in opaque white globular aggregates on colourless cubes of fluor. Other specimens exemplify the forms assumed at Ecton by crystals of galena (No. 1023) and of copper-pyrites (Nos. 1024, 1025).

---

## DIVISION 2.

### MINERALS OF WEST CUMBERLAND AND NORTH LANCASHIRE.

#### HÆMATITE DEPOSITS.

(Nos. 1031 to 1098.)

The hæmatite deposits of North Lancashire and West Cumberland have so much in common that, notwithstanding their topographical severance, they may be conveniently studied together.

In West Cumberland the ore-deposits are in the Carboniferous Limestone series of Cleator Moor and its neighbourhood; whilst in North Lancashire the ore-field lies north of Morecambe Bay, in the district of Furness. Taking their names from neighbouring towns, the former is sometimes known as the Whitehaven district and the latter as the Ulverstone district.

These hæmatite deposits rank among the most important and most interesting ore-bodies in Britain—important industrially in consequence of the large quantity and high value of the ore; whilst they are interesting scientifically in that they yield a great variety of minerals, and these of exceptional beauty.

From the discovery of stone celts in certain old workings in Furness, it has been conjectured that the ore must have attracted attention in prehistoric times, perhaps for use as a pigment. Be this as it may, it is probable that the ore was not neglected by the Romans. The earliest documentary evidence with regard to hæmatite mining in Cumberland goes back to the twelfth century, and since that time the industry appears to have been carried on more or less continuously. But the great development of hæmatite mining was due to the introduction of the Bessemer process, soon



after the middle of the nineteenth century, when the ore, by reason of its freedom from phosphorus, came to occupy a supreme position as a material for the production of pig-iron suitable for conversion into Bessemer steel.

According to official statistics, Cumberland furnished during 1902 as much as 1,086,391 tons of iron-ore, with an average of 52 per cent. of metal, valued at £787,633; whilst North Lancashire yielded during the same year 482,884 tons of ore, averaging 50 per cent. of iron, and valued at £281,682.

*Hæmatite, etc. (Nos. 1031 to 1046).*

The character of the ordinary *Hæmatite* or *red iron-ore* is illustrated by such a specimen as No. 1031. It is a hard massive mineral substance, of a bluish-purple colour. Such ore may contain cavities in which the hæmatite will take the form of botryoidal or reniform masses, known as *kidney ore*, as exemplified by Nos. 1032 and 1033. Larger specimens of similar character will be found in the Wall-case 48; whilst some exceptionally large masses are exposed on a pedestal between the Wall-cases 51 and 52. Certain pieces of this massive ore present the appearance of having been hammered or beaten on the surface. The mineral, though dark-coloured in mass, gives a reddish-brown powder when scratched, justifying its name.\* The surface may in some cases be very lustrous, and almost black, the colour being probably due to superficial alteration to limonite. On fracture, the reniform masses display a fibro-radiate structure, beautifully shown by No. 1033; and in some cases a concentric structure is also exhibited, the material having been deposited in concentric zones, so that it tends to break in successive shells, with smooth curved surfaces, as in Nos. 1035, 1036. The constituent fibres in some cases attain a length of several inches. Some fine examples of the perfectly conoidal fracture which the mineral often presents are seen in No. 1034. The hard ore with conical fracture is known locally as *pencil ore*. Such ore is usually very closely grained or compact, and in consequence of its hardness is much valued as a burnisher. Examples of hæmatite burnishers as used by book-binders for giving lustre to the gilt edges of books will be found in the case of abrasive materials in the Hall, on the east side of the entrance to the Museum. The hard ore, being employed for smelting, is known also as '*blast ore*.'

Whilst much of the compact hæmatite is of this hard nature, other kinds occur which are extremely soft. This is notably the case in Furness (No. 1037). A specimen of soft greasy red ore, forming the substance known as *ruddle*, is shown in No 1038. As the soft ore is used for lining the hearths of puddling furnaces it is sometimes

---

\* *Hæmatite*, literally 'bloodstone,' from *αἷμα* (*haima*) "blood;" the streak giving the colour of dried blood. This mineral is to be distinguished from the ornamental stone called by jewellers 'bloodstone,' which is a dark green red-spotted chalcedony.

termed *puddle ore*. Some of this is of dark colour, containing more or less manganese. The "black muck" of Ulverstone is a dark brown substance, consisting of the oxides of iron and manganese, with much silica.

Deposits of hæmatite in limestone are very irregular in shape, in magnitude, and in distribution; but it is notable that they generally occur in the neighbourhood of faults. Mr. J. D. Kendall has classified the deposits, so far as shape is concerned, into those which are *bed-like*, *vein-like*, and *dish-like*. In many cases the ore-bearing limestone is covered with glacial drift, or boulder-clay; and in order to discover the irregular deposits of ore, explorers are in the habit of probing the ground with iron-shod rods, the presence of a deposit of hæmatite being indicated by a red mark which appears at the end of the rod whenever ore is struck.

Many and varied are the views which have been advanced from time to time in order to explain the origin of the hæmatite and its distribution. Some authorities have seen in this ore evidence of direct volcanic activity; others have regarded it as a secondary formation, deposited in caverns or washed into fissures in the limestone; whilst others again have viewed the hæmatite as the result of the dehydration of pre-existing bodies of limonite, or brown iron-ore. Possibly these views are not mutually exclusive. The origin of the ore-deposit is one thing; the origin of the ore itself another, and in a general view of the whole subject there may be room for several hypotheses.

Much evidence has accumulated in recent years tending to show that ore-deposits such as those of Cumberland and Lancashire have been formed in most cases by the substitution of some iron compound for the original limestone. The ore has gradually replaced the rock.\* It is not that the hæmatite has generally been carried into pre-existing fissures and caverns in the limestone—though this may sometimes have occurred, but the rock itself has suffered a metasomatic change, whereby the carbonate of calcium in the neighbourhood of certain fissures has been replaced molecularly by iron-oxide. Those who have made a special study of the deposits, like Mr. J. D. Kendall and Mr. J. G. Goodchild, take this view; but with regard to the exact way in which the substitution was effected there is much divergence of opinion. Probably the change was not only very slow but indirect.

Mr. Kendall has argued in favour of the iron having been introduced by volcanic activity as ferric chloride.† The reaction of this body with the limestone might form calcium chloride and ferric oxide, with liberation of carbonic acid; and, given an elevated temperature, the oxide of iron might be formed in the anhydrous

---

\* See, for instance, "Genesis of Iron-ores by Isomorphous and Pseudomorphous Replacement of Limestone, etc." By James P. Kimball. *Am. Jour. Sc.*, [3] vol. xlii (1891), p. 231.

† "The Iron-ores of Great Britain and Ireland." By J. D. Kendall (1893), p. 303.





condition. Mr. Goodchild regards it as more likely that the iron was introduced from the red rocks which probably at one time covered the limestone,\* and in this view he is supported by many geologists, who claim a similar origin for certain deposits of iron-ore elsewhere.

The Carboniferous rocks of the hæmatite districts were probably at one time overlain by a mantle of Permian and Triassic strata. Meteoric waters charged with carbonic acid, filtering through the red strata would dissolve the iron, and, in the presence of reducing agents, might carry it off in a ferrous state. When such a solution percolated through the underlying limestone, a reaction might be set up, whereby ferrous carbonate would take the place of calcium carbonate. The unstable iron carbonate might ultimately form, under oxidising influences, ferric oxide. The anhydrous condition of the native oxide offers a difficulty, inasmuch as water would play its part in this reaction, and the dehydration of ferric hydrate at normal temperatures is not readily effected; but Mr. Goodchild has suggested that the introduction of the hæmatite was probably connected with the volcanic activity which prevailed in the north-eastern parts of the British area in early Tertiary times. The formation of the anhydrous oxide seems to require in most cases a moderately elevated temperature.

In support of the metasomatic origin of the hæmatite, Mr. Kendall has pointed to the fact that the ore passes in many cases by insensible gradations into the neighbouring limestone; or, as the miners phrase it, the ore and the rock have "grown together." Some of the ore presents exactly the appearance of the adjacent rock stained red, the hæmatite being stratified and jointed, like the limestone, and having the same dip. Moreover, there are in the body of the ore certain partings and nests of shale, which must have been present in the pre-existing rock, the shaly partings in some cases running through the ore in such a way as to prove that they must have been in their present position before the ore was formed.

But probably the most conclusive evidence of replacement is found in the pseudomorphs and fossils of the hæmatite. The specimen No. 1043, from the Parkside Mines, near Frizington, shows a group of scalenohedral crystals originally of calcite, but now composed of hæmatite. Here the subtle molecular change has been effected without disturbance of external form, so that the red iron-ore has taken the exact shape of the pre-existing dog-tooth spar. The cavernous texture of the pseudomorph suggests that the alteration was accompanied by a shrinkage of volume.

Occasionally, too, fossils are found in the hæmatite. The hard structures of corals, crinoids, brachiopods, and certain mollusca,

---

\* "Contribution towards a List of the Minerals occurring in Cumberland and Westmoreland." *Trans. Cumberland Assoc.*, Part VII. (1882), p. 116; "Some Observations upon the Mode of Occurrence and the Genesis of Metalliferous Deposits." *Proc. Geol. Assoc.*, vol. xi. (1889), p. 62.

have been found either mineralised in hæmatite or represented by casts in the ore. No. 1044 shows a crinoid stem, in which the calcareous matter has been replaced by hæmatite, with perfect retention of the original form.

If such replacement can be proved to have taken place in the case of a crystal or of a fossil, there is no difficulty in extending the phenomenon, and conceiving that it may have been carried out on a large scale in certain rock-masses. In limestone districts it has often been observed that the rock in the neighbourhood of an ore-deposit is more or less magnesian; and this has led to the view that partial dolomitisation of the limestone may be the first step towards the formation of the ore.

Whilst admitting that most of the hæmatite in the North of England has probably been formed by the chemical alteration of limestone, it need not be denied that in some cases the mineral may have been formed by chemical precipitation, or even by mechanical deposition in free cavities in the rock. If the dissolution of the limestone by acidulated waters proceeded at a greater rate than the introduction of the ferruginous matter, open spaces would be left, and these might become receptacles for secondary deposits of iron-ore. Mr. J. L. Shaw holds that the hæmatite has in certain cases been deposited in caverns.\*

The specimen No. 1042, from Ulverstone, is an example of hæmatite occurring as a pseudomorph after crystals of barytes, of the characteristic crested habit. Here the formation of the hæmatite must obviously have been subsequent to that of the barytes. It may be noted that C. Doelter found hæmatite to be soluble in distilled water at 80° C., and to be re-deposited in crystals.†

In the ordinary massive hæmatite of Cumberland there are occasional cavities called *loughs*, and on the walls of these hollows the ferric oxide is sometimes found crystallised in the brilliant form of *Specular iron-ore* or *iron-glance*. A small suite of specimens, Nos. 1039 to 1041, shows this mineral in dark steel-grey or black lustrous crystals, of tabular or lenticular habit, associated with finely crystallised quartz—an association often observed with specular iron-ore elsewhere.

Hæmatite is sometimes slightly magnetic, and this is probably due to admixture with a little magnetite, produced perhaps by deoxidation of the ferric oxide. Magnetic iron-ore, however, is never found in definite form in the ores of Cumberland and Lancashire.

The native sesquioxide of iron suffers hydration, and thus forms several hydrates. *Turgite*, or *hydro-hæmatite*, is the name given to a hydrate having a red streak; whilst *Göthite* and *limonite*, are ferric hydrates with a brown streak. The specimen No. 1045

---

\* "The Hæmatite Ores of Cumberland." By James Leslie Shaw. *Trans. Fed. Inst. Min. Eng.*, vol. iii. (1892), p. 580.

† *Min. Mit.*, Bd. 21. (1890), p. 324.



from Ulverstone, is an example of the variety of goëthite called *Lepidocrocite*—a name denoting the fibro-scaly structure frequently presented by this mineral.

*Quartz (Nos. 1047 to 1054).*

Silica is widely diffused through the hæmatite of Cumberland and Lancashire. The massive ore contains vacuities, varying in size from microscopic pores to cavities of considerable capacity. In the kidney-ore the minute pores when present are usually empty, or nearly so; but in the common kinds of compact ore the pores, usually very numerous, are filled to a greater or less extent with quartz. In this way the hæmatite becomes a siliceous ore, the silica shown on analysis being due to this minutely disseminated quartz. The more siliceous the ore, as Mr. Kendal remarks, the more numerous are these quartz-filled vacuoles. It is as though the whole body of the ore had been suffused at some period with a siliceous solution, probably in a heated state, and that the liquid had deposited the silica in the pores of the mineral-mass.

In addition to these minute vacuities the hæmatite frequently presents cavities, or "loughs," which may reach a considerable size, some measuring as much as a yard across. The walls of these cavities are, in many cases, studded with crystals of quartz and other minerals for which the hæmatite mines have become famous. It is by robbing these cavities of their sparry garniture that we obtain those beautiful crystals which adorn all our collections, and to which the remainder of this Case is devoted.

The suite of specimens, Nos. 1047 to 1054, illustrates the characteristic features of the *Quartz* yielded by the hæmatite deposits. The crystals are usually hexagonal pyramids, or where fully developed bi-pyramids, the planes of the prism being generally subordinate. No. 1048 shows bold pyramids measuring 2 ins. along the polar edges. Much of the mineral is of a brown colour, forming *smoky quartz*, and the brown tint is in some cases so deep that the mineral appears black by reflected light, though the thinner parts near the edges of the crystal are brown by transmitted light. The colour of smoky quartz may usually be expelled by heating, and is referred to the presence of an organic pigment, perhaps, according to Forster, a compound of carbon and nitrogen, but more probably a hydrocarbon, as pointed out by Kraatz-Koschlau and Lothar Wöhler.\* The presence of titanium, as sesquioxide, in a state of solid solution in the smoky quartz, has also been suggested by E. Weinschenk.†

In many cases the quartz during its crystallisation has mechanically entangled some of the iron-ore, and has thus become turbid and tinted. Several specimens illustrate this formation of *iron quartz* (Nos. 1051 to 1054); and in No. 1054 the crystals present a brilliant scarlet colour due to inclusion of finely divided hæmatite.

---

\* *Min. Mit.*, vol. xviii. (1899), p. 326.

† *Journ. Chem. Soc.*, vol. lxx., part ii. (1896), p. 654.

*Calcite, etc. (Nos. 1055 to 1078).*

Few British minerals surpass in beauty the crystals of calcite which have been yielded abundantly in recent years by the hæmatite mines of Cumberland and North Lancashire. A large series of these specimens is here exhibited, whilst others will be found in Section J of the central Horse-shoe Case, and a few of exceptional size in a glass case opposite Wall-case 34.

Some remarkable discoveries of calcite crystals were made in 1888 in the neighbourhood of Egremont, and described by Professor Miers.\* The collection includes a considerable number of specimens from this locality, with others from the Furness district. Many of the crystals are colourless pellucid six-sided prisms, terminated by the rhombohedron (Nos. 1056 to 1058); other clear crystals are acute scalenohedra (Nos. 1060 to 1062), whilst others again are complex or highly modified crystals. The most interesting are the twin-crystals, which have been fully described by Miers, who has figured some of the principal types.† Some assume the habit of the famous butterfly-twins and heart-shaped doublets of Eyam, in Derbyshire (see No. 917, p. 132), which were discovered many years ago, and are now extremely rare; but the Cumberland specimens, as seen in Nos. 1063 to 1066, are in many cases much larger and more transparent than those from Derbyshire.

Many of the calcite crystals, from their association with the red-iron-ore, are more or less tinted, or even deeply coloured, with oxide of iron (Nos. 1062, 1072); thus the crystals from the Stank Mine, in Lancashire, are in many cases very effectively tinted. In some cases a yellowish-brown ochreous substance has been mechanically entangled in the crystals, thus producing more or less opacity; and it is noteworthy that the inclusions are in certain cases locally distributed, so that part only of the crystal will be opaque and brown, whilst the rest remains limpid and colourless, as seen in Nos. 1068 to 1070.

*Dolomite*, or lime-magnesia carbonate, a mineral not uncommon in the iron-bearing limestones, is represented by the series of specimens Nos. 1073 to 1078. These show the mineral in rhombohedral crystals, with curved faces, associated with specular iron-ore and quartz. The *pearl-spar*, so called from its nacreous lustre, usually displays a superficial brown colour, due to the presence of iron, and is often iridescent, as illustrated by several of these specimens.

*Aragonite (Nos. 1079 to 1083).*

Since the hæmatite deposits of Cumberland and Lancashire occur in limestone, it is by no means surprising that they should be freely associated with carbonate of lime, but what is rather noteworthy is the fact that this crystallised carbonate occurs not

\* "Calcites from the neighbourhood of Egremont, Cumberland." *Min. Mag.* vol. viii. (1889), p. 149.

† "Mineralogy," pp. 395, 397.



only in the usual form of calcite but also in the less stable form of *Aragonite*. The finest British aragonites occur with the hæmatite of Cleator Moor. A series of typical specimens is here exhibited (1079 to 1083), and some larger examples will be found in Section K of the Horse-shoe Case.

Very characteristic are the long slender crystals of aragonite, showing acute pyramids belonging to the orthorhombic system. These spire-like crystals are often aggregated in radiating groups, which diverge from the matrix. The mineral is very brittle, and the sharp points of the tapering crystals are often broken off, so that they present a premonitory aspect. The cross fracture is sub-conchoidal, and the lustre of the broken summit inclines decidedly to a resinous aspect, whilst the remainder of the crystal exhibits on its faces a glassy lustre.

It was shown many years ago by the experiments of Gustav Rose—and his results have been confirmed and extended by later observers—that aragonite may be deposited from solution of calcium carbonate at high temperatures, whilst calcite is deposited from cold solutions. In the hæmatite districts the two species occur together, and experiment has proved that although calcite alone is precipitated at low temperatures, both aragonite and calcite may be deposited from warm solutions, though the aragonite predominates. Warm calcareous solutions might readily circulate through the limestone if, as Mr. J. G. Goodchild has plausibly conjectured, the hæmatite deposits were formed in connection with the volcanic activity of the Tertiary period.

According to Dr. H. Credner, the character of the precipitated carbonate of lime is partly controlled by the degree of concentration of the solution. From a pure cold solution, saturated or moderately strong, it is thrown down as rhombohedra of calcite; but if the solution be more dilute it may be precipitated as prismatic aragonite.\*

It should also be noted that the character of the calcareous deposit may be determined by the presence of foreign matter in the solution from which precipitation occurs: thus aragonite may be thrown down from solutions containing with the calcium carbonate more or less sulphate of calcium or certain salts of strontium, barium, or lead.

The student may find it convenient to contrast the characters of the two species of dimorphous carbonate of lime:—

<i>Calcite.</i>	<i>Aragonite.</i>
Rhombohedral system.	Orthorhombic system.
Spec. grav. 2·7	Spec. grav. 2·9.
Hardness, 3.	Hardness, 3·5 to 4.
Deposited from cold solutions, or from solutions containing alkaline silicates.	Deposited from warm solutions, or from solutions containing gypsum, strontianite, etc.†

\* *Neues Jahrb.*, 1871, p. 288.

† "Chemische Mineralogie." Von Dr. Reinhard Brauns. Leipzig: 1896, p. 156.

*Barytes, etc. (Nos. 1084 to 1095).*

Fine crystals of *Barytes*, or sulphate of barium, are not infrequently associated with the ore deposits of the Northern hæmatite districts, and numerous excellent examples have been yielded by the extensive mining operations of recent years. A rather large series of typical specimens of barytes is here exhibited; and the visitor seeking further acquaintance with the mineral may study the fine specimens in Section G of the Horse-shoe Case; nor should he overlook the noble crystals in the lower part of the glass case which stands opposite to Wall-case 34.

Most of the crystals are of tabular habit, but their aggregation gives rise to varied and in some cases quite picturesque groups, as in Nos. 1088, 1089. By development along certain axes the crystals become elongated, like those in No. 1087. Great diversity of colour is exhibited by this species: whilst some crystals are colourless (No. 1084), others are of a delicate blue tint, suggestive of celestine (Nos. 1085, 1086); certain specimens are of sea-green colour (1092), others brownish-green (1094) or brownish-yellow (1089); and in others again the brown colour becomes deepened.

A zonal structure is seen in such crystals as Nos. 1089 and 1094. The mode in which the mineral grows by accretion of matter from without is strikingly illustrated by the "Phantom Crystals," 1093 and 1094. Here the process of development of the crystal must have been arrested for a while; and after this pause fresh matter was deposited, so that the nucleus became invested by a secondary growth, whilst some slight difference in the character of the successive deposits enables the stages of development to be recognised.

A few other minerals from the hæmatite deposits are placed at the end of the series. These include some examples of *iron pyrites* (Nos. 1096, 1097), remarkably attractive by the brilliant iridescence of the surface. The specimen No. 1098, from Lindel-in-Furness, is a pseudomorph of dark-coloured hæmatite after some cubic species. It has been suggested that this was pyrite, and the conversion of pyrite into hæmatite has been recorded from many localities. Such pseudomorphs have been described, for example, from Torquay by Mr. R. H. Solly and Dr. A. Hutchinson.\* But such alteration is by no means common, and it seems more likely that the original cubic mineral in the Lancashire specimen was fluorspar, as described by Professor Miers in similar pseudomorphs from the Stank Mine and from Dalton-in-Furness.†

---

\* "Pseudomorphs of Hæmatite after Iron Pyrites." *Min. Mag.*, vol. viii. (1889), p. 183.

† "On some British Pseudomorphs." *Ibid.*, vol. ix. (1897), p. 269.



## CASE IX.

## DIVISION 1.

## MINERALS OF CUMBERLAND.

## MINERALS OF THE CALDBECK FELS AND THE LAKE DISTRICT.

(Nos. 1099 to 1166.)

By far the larger part of this section of Case IX. is occupied by a series of minerals from the neighbourhood of the Caldbeck Fells, a wild district to the south-east of Wigton, in the northern part of Cumberland. Numerous mineral-veins in this district long ago tempted exploration, for sake of their ores of lead and copper. At the present time, however, there are no workings in this locality.

The minerals here exhibited range themselves in two groups. One group rather recalls the minerals of the Cornish tin-lodes, for although the veins of quartz seem to be destitute of tinstone they yield wolfram, scheelite, molybdenite, mispickel, apatite, and certain minerals of bismuth. Such an assemblage at once suggests genetic relations with an eruptive magma, like that of the neighbouring granitic rocks.\* The minerals may have been introduced into the veins from plutonic sources, while the magma was in a highly heated condition. Although the minerals are rather vaguely referred in most collections to the Caldbeck Fells area, Mr. Goodchild has pointed out that the precise locality which has yielded most of them is the neighbourhood of Brandy Gill, where the rocks are traversed by parallel veins running in a north and south direction.

The second group is formed by the lead-and copper-ores of Caldbeck Fells, which appear to be of later date than the minerals just indicated. These ores come chiefly from Red Gill and Roughten Gill, or, as it is sometimes spelt, Rowtin Gill. Galena, blende, and chalcopyrite seem, as usual, to have been the original minerals, but near the outcrop of the veins they have given rise to a number of secondary products, including minerals of great beauty, like linarite. Mr. Goodchild has argued, with much plausibility, in favour of the view that the later infilling of the veins was due to the thermal waters brought up during the great volcanic outbursts of Tertiary times, or immediately subsequent thereto.† Apart

\* For the igneous rocks of the district see Mr. Alfred Harker's papers in *Quart. Journ. Geol. Soc.*, vol. i. (1894), p. 311; vol. li. (1895), pp. 125, 139.

† "Some Observations upon the Mode of Occurrence and the Genesis of Metalliferous Deposits." *Proc. Geol. Assoc.*, vol. xi. (1889), p. 45.

from direct outflows, the formation of a vast system of dykes sufficiently demonstrates, as Sir A. Geikie has forcibly shown, how intense and widespread must have been the subterranean activity in the northern part of the British area during the Tertiary period.\* Waters laden with mineral matter would travel along the heated highways opened up by the fissuring of the rocks, and deposition might occur on reduction of temperature and diminution of pressure, so that the latest phases of vulcanicity would probably represent the most favourable conditions for mineral precipitation in the veins. Mr. Harker has suggested, though with due reserve, that the gabbro and granite of Carrock Fell may be of Tertiary age.†

*Apatite (Nos. 1099 to 1104).*

No part of Britain, with the exception of Devonshire, has yielded finer crystals of *Apatite* than those which have occasionally been found in the quartz-veins at the foot of Brandy Gill. A suite of fine specimens is here exhibited, showing the mineral in prismatic crystals, striated longitudinally and terminated by the basal pinacoid. Some specimens, like No. 1100, are of a beautiful blue colour, like typical beryl; others are of a celadon-green tint (No. 1099), whilst others again are not uniformly coloured, but the pale green passes at one extremity into a delicate pink, rather like the well-known parti-coloured tourmalines (Nos. 1101, 1102). The apatite is associated, in the quartz matrix, with gilbertite (Nos. 1099 to 1103), and in one specimen (No. 1104) is accompanied by wolfram—an association rather suggestive of that occurring in Cornwall. No analysis of the Cumberland apatite seems to have been recorded.

*Wolfram and Scheelite (Nos. 1105 to 1111).*

In connection with the Cornish tin-lodes, *Wolfram* or *wolframite* has already been described (p. 30). It is one of a small group of minerals crystallizing in the monoclinic system. There is a rare species called Ferberite, which is essentially a tungstate of iron, and another called Hübnerite, essentially a tungstate of manganese, but in Wolfram the two compounds occur as an isomorphous mixture, so that the ratio of the two metals, iron and manganese, is subject to variation.

No. 1108 is a specimen of *wolfram ochre* or *tungstic ochre*, known as *tungstite*, which is a trioxide of tungsten, formed by the alteration of wolfram. In several of the specimens, as Nos. 1109 and 1110, the wolfram is seen in association with *Scheelite*. This mineral occurs in Cumberland well crystallised in tetragonal bi-pyramids, as illustrated by Nos. 1110 and 1111, where the bold crystals exhibit the characteristic brownish-yellow colour, associated with a lustre almost adamantine. This species, named after the Swedish chemist Scheele, who first detected tungsten, is a tungstate of calcium. Although

\* "The Ancient Volcanoes of Great Britain," vol. ii., book viii.

† Geol. Surv. Mem., on Skye (1904), p. 170.



it may have originated in some cases from wolfram, the converse change is not uncommon. Pseudomorphs of wolfram after scheelite point to the substitution of iron and manganese for calcium. Such change has been described, for instance, by Mr. W. H. Hobbs, as occurring at Trumbull, Connecticut, where wolfram is mined.\* Scheelite is, in some cases, a companion of gold ores, as described by Sir C. Foster in the Pesterana district.

*Molybdenite, etc. (Nos. 1112 to 1115.)*

In most scheelite molybdenum is present, to a greater or less extent replacing the tungsten, and it is said that the darker the colour of the scheelite the greater is generally the proportion of molybdenum.† Between molybdenum and tungsten there is, indeed, much relationship. Molybdenum occurs native as a disulphide forming the mineral called *molybdenite*. Some excellent specimens of this rather rare species are here exhibited (Nos. 1112 to 1113) showing the mineral in soft, brilliant graphite-like scales and crystalline plates associated with wolfram and scheelite in the quartz-veins of Brandy Gill. In No. 1114 the molybdenite is coated with a thin, yellow incrustation of *molybdite*, of *molybdic ochre*, an oxide evidently formed at the expense of the sulphide, on which it is parasitic.

Molybdenite occurs in thin, metallic scales in certain granitic and other igneous rocks. It is found, for example, in the joints of the Shap granite,‡ and in the granite of Mount Sorrel,§ where it is known to the quarrymen as "lead."

It is interesting to note that Mr. Goodchild has recorded the occurrence of a mineral believed to be *Wulfenite*, or molybdate of lead, in one of the gills running up from the Cawda to the west side of Carrick.|| As both molybdenite and galena occur in the veins of this district, the conditions for the formation of such a mineral are not far to seek.

*Grünlingite (Nos. 1116 to 1118).*

The two rhombohedral metals, tellurium and bismuth, occur in combination as *telluric bismuth*; and the related elements, selenium and sulphur, may also be present in variable proportion. A combination containing  $\text{Bi}_2 \text{Te}_2 \text{S}$  has been distinguished as a definite species under the name of *Tetradymite*. Such a mineral occurs with the gold ores of North Wales (p. 130), and it has long

\* Twenty-second Annual Report U.S. Geol. Surv., Part ii., 1901.

† H. Traube in *Neues Jahr. Beilage* Bd. vii. (1890), p. 232. The Cumberland scheelite contains 0.35 per cent. of  $\text{MoO}_3$ .

‡ "The Shap Granite." By Alfred Harker and J. E. Marr. *Quart. Journ. Geol. Soc.*, vol. xlvii. (1891), p. 266.

§ "On the Occurrence of Molybdenite in Leicestershire." By Dr. C. Le Neve Foster, *Geol. Mag.*, vol. iii. (1866), p. 525.

|| "Wulfenite at Caldbeck Fell." *Geol. Mag. [N.S.]*, Dec. 2, vol. ii. (1875), p. 565.

been known that a similar mineral is occasionally found in the quartz-veins of Brandy Gill. An allied mineral from Brazil has been called *Joseite*. The Cumberland mineral was examined long ago by Rammelsberg, but fresh analyses were made a few years back by W. Muthmann and E. Schröder, in Munich. They found that it contained about 12 per cent. of tellurium, leading to the formula  $\text{Bi}_2\text{S}_3\text{Te}$ , and as this differs markedly from the formula of true tetradyomite they regarded the Cumberland mineral as a new species, for which they proposed the name Grünlingite, in compliment to Dr. J. Grünling, the Curator of the Mineral Collection in Munich.\* The mineral occurs in cleavable laminar masses, with brilliant metallic lustre, and from certain measurements made in Dr. Groth's laboratory by Mr. Herbert Smith, the mineral seems to agree with tetradyomite in its system of crystallisation.

*Pyromorphite, etc. (Nos. 1119 to 1138).*

Among the minerals yielded by the lead-lodes of the Caldbeck Fells, some of the finest are specimens of *Pyromorphite*, formerly obtained from shallow workings at Roughten Gill. The rather extensive series of specimens, Nos. 1119 to 1130, will serve to illustrate the varieties presented locally by this species. Most of the specimens show the pyromorphite in crystals of prismatic habit, the hexagonal prisms being in some cases slightly hollow or cavernous. The mineral is called *green ore* or *brown ore*, according to its colour, but some of the finest crystals are of greenish yellow tints. However deep the colour, the streak of the mineral is nearly white. White pyromorphite, like No. 1130, generally contains calcium, and is regarded as an isomorphous mixture with apatite.

Pyromorphite is a chloro-phosphate of lead, which in most cases appears to have been formed from galena. Pseudomorphs of pyromorphite after galena are known, but curiously enough the reverse change is also attested by pseudomorphs of galena after pyromorphite, or "blue lead-ore," as noticed at p. 55.

The presence of apatite rather abundantly in the Caldbeck Fells district suggests that it may be genetically connected with the pyromorphite. Apatite is readily soluble in water containing carbonic acid, as Professor Truchot has shown, and such a solution reacting with cerussite derived from galena, would give rise to phosphate of lead. This at least is the explanation suggested by M. Gonnard to explain the origin of the pyromorphite of Pontgibaud.†

Associated with the pyromorphite of Roughten Gill, there occasionally occurs a smalt-blue or lavender-coloured mineral, formerly

\* "Ueber die Zusammensetzung einiger Tellurmineralien." *Zeits. Kryst. u. Min.*, vol. xxix. (1898), p. 140: "Grünlingit, ein neues Mineral," p. 144.

† "De la genèse des phosphates et arseniophosphates plombifères de Roure et de Rosiers (Pontgibaud)." *Bull. Soc. Min. Fr.*, vol. vi. (1888), p. 35.



regarded as a kind of calamine, but shown by Professor Miers, from examination by Mr. G. T. Prior, to be a phosphate of lead and aluminium.\* Specimens are seen in Nos. 1132 to 1134. Analyses by Mr. E. G. J. Hartley, in the mineralogical laboratory at Oxford,† have proved it to be identical with a mineral from Georgia, described many years ago by Professor Shepherd under the name of *Hitchcockite*. The blue colour is probably due to the presence of a small proportion of copper. The Cumberland hitchcockite in some cases invests, and in others appears to replace, the pyromorphite, thus giving rise to pseudomorphs, as well seen in the specimens here displayed.

In pyromorphite, the phosphorus may be replaced to a greater or less extent by arsenic, and the species may thus pass gradually into the chloro-arsenate of lead, known as *Mimetite*. This is generally a yellow or brown mineral, sometimes beautifully orange-coloured, as well shown by the fine specimens Nos. 1135 to 1138. These specimens came from Dry Gill, at a short distance to the east of Roughten Gill, where the mineral occurred formerly in such abundance that it was worked commercially. The crystals are aggregated in six-sided groups, which, by their general shape, are suggestive of miniature barrels, and the pronounced curvature of the prism faces has earned for this variety the name of *Campylite*. In some cases the curvature is so great that the mineral forms almost spherical masses. The campylite was associated, as some of the specimens here show, with psilomelane and with barytes, well seen in No. 1135. According to Greg and Lettsom, it was worked not only as an ore but for direct use in the manufacture of flint-glass, to which it was reputed to impart exceptional brilliancy.‡ The mineral contains a small proportion of phosphate, as is usually the case with mimetite; whilst conversely most pyromorphite shows traces of the arsenate. The source of the arsenic in mimetite is probably to be found in the mispickel, or arsenical pyrite, not uncommon in the veins of the Caldbeck Fells district.

It is noteworthy that the two isomorphous minerals, the chloro-phosphate and the chloro-arsenate of lead exhibit certain optical anomalies, pyromorphite being sometimes and mimetite always biaxial.§ Professor Miers remarks that "the pyromorphite of Roughten Gill seems to consist in the middle of uniaxial pyromorphite and at the side of biaxial mimetite. Since, however, pure mimetite is almost unknown, the biaxiality of the mineral may be really due to strains set up by isomorphous intermixture."¶

\* "On some British Pseudomorphs." *Min. Mag.*, vol. xi. (1897), p. 272.

† "On the Constitution of the Natural Arsenates and Phosphates." Part iii. "Plumbogummite and Hitchcockite," *Ibid.*, vol. xii. (1900), p. 223. Also, Prof. Miers's "Notes on the Hitchcockite, etc." *Ibid.*, p. 239.

‡ "Mineralogy of Great Britain." p. 407.

§ Optical anomalies are apparent irregularities in the relationship normally subsisting between optical characters and crystalline symmetry.

¶ "Mineralogy," p. 515.

*Cerussite, Anglesite, and Linarite* (Nos. 1139 to 1146).

The oxidised ores of lead, occurring within the zone of weathering in the deposits of Roughten Gill and Red Gill, include not only the phosphates and arsenates, but, as might be expected, the more common minerals in which lead appears as carbonate and sulphate. As such minerals have been described already in connection with the Derbyshire collection, (pp. 138, 139) very little need here be added. Nos. 1139 to 1142 are examples of crystallised *Cerussite*, or lead carbonate, associated in No. 1141 with malachite, whilst No. 1143 is a specimen of the less common mineral *Anglesite* or lead sulphate.

Some attention, however, is demanded by the rare and beautiful species called *Linarite*, of which some excellent specimens are here shown (Nos. 1144 to 1146). This mineral was originally noticed by Sowerby, who regarded it, pardonably enough in his day, as a blue carbonate of copper.\* It was afterwards studied chemically and crystallographically by Mr. H. J. Brooke, with the result that he determined it to be a "cupreous sulphate of lead."† Brooke conferred upon it no specific name, but it was subsequently called *Linarite*, from Linares, a mining locality in the south of Spain. The specimens studied by Sowerby and by Brooke were from Scotland.

*Linarite* occurs in crystals of tabular and prismatic habit, belonging to the monoclinic system, and presenting a deep azure-blue colour, with a brilliant vitreous lustre. It is a basic sulphate of lead and copper, and has no doubt been formed by the oxidation of lead and copper sulphides, such as occur in the ore-deposits of Cumberland. The late Mr. Patrick Dudgeon detected it in the cavities in slag from old Roman lead-smelting works, in Dumfries, where it had evidently resulted from alteration by exposure.‡

The minerals *Leadhillite* and *Caledonite* have been recorded as occurring with the *linarite* of Cumberland, but no specimens are at present in the collection. (For these species, see p. 208.)

*Malachite, Brochantite, etc.* (Nos. 1147 to 1155).

Wherever copper-ores are subjected to meteoric influences, *Malachite* is likely to be formed, and by its colour to assert its presence. In the ore-deposits of Caldbeck Fells, the copper-pyrites, by alteration, has yielded this conspicuous mineral in many localities; and some fair specimens are here exhibited (Nos. 1147 to 1150). The mineral is a basic cupric carbonate, appearing generally in acicular crystals, or in fibrous masses and incrustations, of bright green or sometimes very dark green colour. In Nos. 1149 and 1150, from Braithwaite, it is associated with white acicular crystals of *cerussite*, showing that superficial agencies acting on mixed ores

\* "British Mineralogy," vol. iii. (1809), p. 5.

† "On a New Lead Ore." *Ann. Phil.*, new ser., vol. iv., (1822) p. 117.

‡ *Min. Mag.*, vol. v. (1884), p. 33.



of copper and lead have brought both metals into the state of carbonates. *Azurite*, or blue carbonate of copper, though occurring in the Caldbeck Fells area, is a rarer mineral than the green carbonate and does not happen to be represented in this collection.

Several examples of the basic sulphate of copper called *Brochantite* are here exhibited (Nos. 1151 to 1153). At Roughten Gill this rare mineral occasionally occurs in small crystals of dark green colour, associated with malachite and chrysocolla. Mr. W. Semmons has insisted on the frequent relationship of the sulphates and silicates of copper.\* Pseudomorphs of chrysocolla after brochantite are known.

A specimen of *Chrysocolla*, or hydrated basic silicate of copper, from Roughten Gill, shows the mineral in the form of small globular masses of bluish-green colour, on a quartzose veinstone (No. 1154).

Rarer than most of the other copper-bearing minerals in this Case is the species termed *Aurichalcite*, of which a beautiful specimen from Roughten Gill is here exhibited (No. 1155). This is evidently a secondary mineral due to the weathering of mixed ores of zinc and copper, since it consists of a basic carbonate of both metals. In consequence of its containing the constituent metals of brass, it was called by the early mineralogists *brass-ore*, or an equivalent name. The aurichalcite here shown occurs in fibres or minute acicular crystals, of a delicate turquoise blue tint, investing quartz. Another Cumberland specimen (No. 1206), will be found in the opposite side of the Case, among the minerals of Alston Moor.

#### *Hemimorphite* (Nos. 1156 to 1161).

The eye of the visitor will be attracted by the beautiful sky-blue colour of the mammillary deposits of this species, as exhibited in the specimens from Roughten Gill. The deposits are laminated and consist of acicular crystals, which owe their colour, it is believed, to the presence of copper, whence the mineral has been called *cupreous calamine*.

Mention has already been made (p. 109) of the confusion in nomenclature with regard to the oxidised minerals of zinc. The term *Calamine*, restricted in this work to the carbonate, is often applied to the silicate, whilst the term *Smithsonite* is used by some authorities to designate the silicate and by others to denote the carbonate. Calamine is a word much too venerable to be displaced, but in order to avoid ambiguity with regard to the smithsonite, it seems well to abolish its use altogether, and to distinguish the hydrous silicate by the term *Hemimorphite*, which was introduced by Kenngott in 1853. The anhydrous silicate, known as *Willemite*, is not recorded among British zinc-ores.

Hemimorphite is commonly described as a hydrated zinc silicate, but since it has been shown that it requires exposure to a red heat before the water is expelled, the mineral may be rather regarded

---

\* "On Brochantite and its Associations." *Min. Mag.*, vol. iv. (1882), p. 259.

as a basic silicate. It crystallises in the orthorhombic system, and the term hemimorphite has reference to the hemimorphic characters of its crystals, that is to say, the opposite ends are crystallographically dissimilar. Most hemimorphic crystals are pyroelectric, or become electric when heated, whence hemimorphite is often called *electric calamine*. That end of a crystal which becomes positively charged as the temperature rises is termed the *analogous* pole, whilst the opposite end, becoming negative, is called the *antilogous* pole. On cooling, the character of the electricity is reversed. The phenomenon is well illustrated by Kundt's method, as applied by Professor Miers, which consists in dusting over the electrified crystal a fine mixture of red lead and sulphur, rendered electric by shaking, when the sulphur adheres to the part which is positively charged and the red lead to the negatively electrified portion.

Zinc silicates may be formed naturally by the reaction of alkaline silicates on sulphate of zinc, resulting from the oxidation of blende. The Cumberland hemimorphite exhibits mammillated forms suggestive of deposition from solution, in the manner of stalagmitic growths.

*Tourmaline, Garnet, etc. (Nos. 1162 to 1165).*

Following the silicate of zinc are a few specimens of other silicates from Cumberland. No. 1162 is an example of *Tourmaline*, from the Caldbeck Fells district, showing the mineral in brown, radiating fibres on quartz.

No. 1163 is a specimen of *Epidote*, from Willow Craig near Keswick; No. 1164 an example of *Garnet* in well-defined crystals from Derwentwater;\* and No. 1165 a piece of Skiddaw slate, enclosing characteristic crystals of *Chiastolite*, a variety of andalusite, well known as a product of contact-metamorphism. In the Petrological Collection there is a large series of rock-specimens from the Lake District of Cumberland and Westmorland, and the visitor may be referred to that Collection for better examples of the various crystallised silicates from the igneous and metamorphic rocks.

*Graphite (No. 1166).*

In parts of the Lake District there are certain veins of copper and lead-ores, whilst minerals containing antimony, nickel, and cobalt have also been recorded. The Keswick copper-mines were formerly of great reputation, and a description—both geological and historical—will be found in the Geological Survey Memoir by the late Mr. Clifton Ward.† But the most interesting mineral of Lakeland is undoubtedly the well-known *Graphite* or *Plumbago*, commonly called *black lead*—the material of the famous Cumberland pencils. In old documents the mineral is referred to under the name of *wad*—a name now generally restricted to certain oxides of

\* The garnet-bearing rocks of Lakeland were studied by the late Mr. E. E. Walker. *Quart. Journ. Geol. Soc.*, vol. lx. (1904), p. 70.

† "The Geology of the Northern Part of the English Lake District." *Mem. Geol. Surv.*, 1876.



manganese—and it is also termed *black cawk*—the term “cawk” being elsewhere applied only to barytes. Only one specimen of Cumberland graphite is shown here (No. 1166), but a rather extensive series of examples will be found in Section B of the Horse-shoe Case and in the drawer under Section E.

The Cumberland graphite, now extremely rare, was found in pipes, strings, and irregular masses called “sops,” which occurred, according to Mr. Ward,\* in association with a dyke, or sill, of altered diorite and with intrusive masses of diabase, in the old volcanic series of Borrowdale. Small veins of quartz run through the diorite, and an old writer speaks of the black-lead as being associated with “quarts and chrystles.”†

Dr. Percy held that the special value of the Borrowdale graphite depended rather upon its peculiar physical condition, upon its state of aggregation more than upon its chemical purity; for, as a matter of fact, it contains a rather considerable proportion of foreign matter, which, on the combustion of the carbon, is left as ash, to the extent of about 12 per cent.‡

The general origin of graphite is a subject by no means free from obscurity. In some cases there can be no doubt that graphite represents an extreme stage of carbonisation of organic matter. Specimens in the Horse-shoe Case, presented by J. Smith, Esq., illustrate the alteration of coal to graphite by the proximity of an intrusive eruptive rock, at Craigmair, near New Cumnock, in Ayrshire.§ In certain graphitic schists the mineral occurs as disseminated black dust, probably developed by contact-metamorphism.

Artificial graphite is familiar to the metallurgist, as occurring in the form of dark lustrous scales in grey pig-iron. Molten cast iron dissolves carbon, and when supersaturated the excess may separate, on cooling, as crystalline graphite. Such a material is known to the workmen as “kish.” Under conditions of great pressure, carbon may be obtained from solution in molten metal not only in the form of graphite, but, as M. Moissan discovered, in the form also of diamond.

An opinion has recently been gaining ground in favour of the origin of natural carbon, in many cases, from the decomposition of metallic carbides, of deep-seated origin. The action of water on such carbides would give rise to hydrocarbons, as M. Mendeleef pointed out, in discussing the origin of petroleum. Professor J. Walther, who has studied the occurrence of graphite in the gneissose rocks of Ceylon, favours the view that the mineral has there resulted from the reduction of certain volatile hydrocarbons.||

\* “The Geology of the Northern Part of the English Lake District,” p. 60. Plans and Sections of the Borrowdale Mine are given.

† “The History of the County of Cumberland.” By William Hutchinson. 1794. vol. ii. p. 220.

‡ “Metallurgy: Fuel, etc.” 1875. p. 103.

§ *Trans. Geol. Soc. Glasgow*, vol. x. (1896), p. 257.

|| “Ueber Graphitgänge in zersetzten Gneiss (Laterit) von Ceylon.” *Zeitsch. Deutsch. Geolog. Gesell.* vol. xli. (1889), p. 359. See also Max Diersche in *Jehrb. d. K.-K. Geol. Reichsanst.*, vol. xlviii. 1898, p. 231.

## DIVISION 2.

## MINERALS OF THE NORTHERN LEAD DISTRICTS.

ORES OF LEAD AND ZINC; BARYTES, ETC.

(Nos. 1167 to 1234.)

Deposits of lead-ore are distributed more or less abundantly through the Carboniferous rocks of an extensive tract of country in the North of England, comprising parts of the counties of Cumberland, Westmorland, Northumberland, Durham, and Yorkshire. This vaguely defined area may perhaps be regarded as having its centre in Alston Moor—a wild district in Cumberland, on the borders of Westmorland, described as being almost the centre of Britain itself.\* The occurrence of the ores in the Northern Lead Districts is similar to that of the corresponding minerals in the Carboniferous Limestone of Derbyshire. The galena is accompanied by zinc-blende, and the veinstuff is composed chiefly of calcite, fluor-spar and barytes, though quartz is present in some of the ore-deposits, especially in those which are located in or near siliceous rocks. Some of the lead-ore, such as that formerly worked in large quantity at Grassington in Yorkshire, is in Millstone Grit.

The Carboniferous Limestone series consists of an alternation of limestones, sandstones, and shales, varying considerably in thickness in different districts, but reaching a maximum of about 2,800 feet, though at Alston Moor its thickness is only about half this aggregate. Intercalated with the Carboniferous strata is the great sheet of intrusive rock known as the Whin-sill, which at Alston Moor is about 120 feet thick, whilst elsewhere it may reach a yet greater development.

The *Lead measures*, or ore-bearing strata, lie between the Whin-sill and the Fell Top Limestone. The Millstone Grit, which must at one time have spread over the whole of the Carboniferous Limestone series of the Pennine range, has been mostly removed by denudation, but patches are left here and there, in some cases of considerable extent. Most of the veins are fault-veins, and the veinstones are much brecciated. The principal workings are, or have been, situated near the upper waters of the South Tyne, the Allen, the Wear, the Derwent, and the Tees.

Several types of ore-repositories are recognised in the northern lead districts. The *Rake veins* known also as *right-running veins*, usually take an approximately east and west course. It is observed that they are generally more productive in hard rock, like limestone, than in soft rock like shale. The *cross-veins*, running roughly north and south, and apparently of later formation than the rakes, have been found to carry much lead-ore when in the Great Limestone, but

---

\* “On the Lead-mining Districts of the North of England.” By T. Sopwith, M.A., F.R.S. *Trans. N. Eng. Inst. Min. Eng.*, vol. xiii. (1864), p. 187.



to yield little in the strata above; whilst in the beds below, the lead is not infrequently accompanied by copper-ore. A third class, including smaller veins containing but little ore, have an intermediate bearing, and are called *quarter-point veins*. There are also the large ore-bodies termed *flats*, or *flots*, which are irregular sheets or flattened pockets often roughly parallel to the stratification, and connected by fissures, vertical or oblique, containing more or less mineral. The cavities in the flats yield some of the finest specimens of crystallised minerals, especially of calcite and fluor.

Although the Alston mines may have been worked at a very remote period, the earliest known reference to them is contained in a document dated A.D. 1131, in which a certain mine, identified with some of the old Alston workings, is referred to as the "Carlisle Silver Mine." \* Some of the galena formerly worked must have been highly argentiferous, and pieces of ore rich in silver have occasionally been found even in recent times. Certain fragments of "float-ore" have yielded, according to Mr. Cameron Swan,† as much as twelve ounces of silver to the ton of lead, though the ore at present worked in the Alston district is by no means rich, the average of Nenthead and of Weardale lead-ore being, according to the same authority, only about seven or eight ounces of silver per ton of pig-lead. It has often been remarked that galena is less highly argentiferous in limestone than in veins running through slates and grits.

The lead-ore of the Alston district is associated with more or less zinc-ore, which is now extensively worked by the Vieille Montagne Co. Though formerly zinc-blende was regarded as worthless and practically a nuisance, it is this mineral which now forms the chief object of exploration in the district.

Thus, according to official statistics, Cumberland yielded in 1902 as much as 7,826 tons of zinc-ore and only 1,273 tons of lead-ore whilst Northumberland produced 3,056 tons of zinc-ore and but 600 tons of lead-ore. On the other hand there were raised in Durham 2,760 tons of lead-ore against thirty-seven tons of zinc-ore; whilst in Westmorland and Yorkshire no zinc-ore was returned, though the former county produced 1,424 tons of lead-ore and the latter 662 tons.

#### *Galena* (Nos. 1167 to 1188).

Some sharply defined crystals of *Galena* are here exhibited from Alston Moor, notably the large cubes, associated with pearl-spar, in No. 1168. In the specimen No. 1169, the galena is crystallised in cubo-octahedra, and the cube-faces are deeply corroded, exhibiting what miners call "seals." Several specimens, such as 1173 and 1174, display an iridescence on the tarnished faces of the galena

\* "The Alston Mines." By the Rev. W. Nall, M.A. *Trans. Inst. Min. Eng.*, vol. xxiv. (1903), p. 392.

† Discussion on the foregoing paper: Remarks by W. J. Cameron Swan of Newcastle-upon-Tyne. p. 406.

crystals. The lead sulphide is associated with calcite in Nos. 1172, 1174; with fluor-spar in Nos. 1176 to 1182; and with quartz in 1167. In No. 1173 the cubic crystals of galena are partly covered with cubes of white fluor, upon which is a small crop of quartz-crystals. No. 1188, a specimen from the Craven district in Yorkshire shows the crystalline galena gradually passing towards the surface into compact cerussite, or lead carbonate.

The origin of galena in limestone rocks has been the subject of much discussion. It has often been suggested that the common association of lead-ore with limestone may have some relation to the organic nature of the rock. From the widespread occurrence of galena in the Carboniferous Limestone, this rock has been called by miners the "Mother of Lead." In some cases plumbiferous solutions may have been reduced by the action of organic matter. Thus, among the specimens in Case 37 illustrating the processes of fossilisation will be found an example of wood mineralised with galena.\* Dr. R. W. Raymond described an iron pickaxe from an old mine in the Cerillos range of New Mexico, in which the eye of the axe had been filled with crystallised galena, probably formed from the reduction of lead sulphate by the decaying wood of the pick-handle. Allusion has already been made (p. 118), to the occurrence of galena in coal, where the de-oxidising action of the carbonaceous matter seems to have been responsible for the reduction of galena from a solution of the sulphate. That the formation of galena has not necessarily required a high temperature is clearly attested by its occurrence in veins traversing coal-seams without altering the adjacent coal. No. 1186 is a specimen, presented many years ago by the Earl of Carlisle, shewing the galena associated with coal as it occurred at Netherland in Northumberland.†

According to the late Mr. Wallace, the formation of the galena is comparatively recent, and may be still going on in the neighbourhood of Alston Moor.‡ In support of this view he called attention to certain small crystals of galena, known as "buttons of ore," which stud the walls of some of the caverns in the district and are believed to be of quite recent formation. This observer, who was a resident in the midst of the mines, held that the lead-ore had been derived from the rocks of the district, through which it had been diffused in small proportion and whence it had been removed in solution. He remarked that those veins which were most productive were the farthest removed from igneous rocks.

\* This specimen is from Freihung in Bavaria, and is exhibited in the Table-case, No. 37, on the opposite side of the Museum, close to Case No. 1 of this collection of British Minerals. The Freihung Mines, which have yielded the tree-stems in which the tissues are partly replaced by galena, are in the Trias.

† On the reducing action of coal and other carbonaceous substances, see Dr. W. P. Jenny, *Trans. Am. Inst. Min. Eng.*, vol. xxxiii (1903), p. 445.

‡ "The Laws which regulate the Deposition of Lead-ore in Veins; illustrated by an examination of the geological structure of the Mining Districts of Alston Moor." By William Wallace. 1861.



Admitting that the galena may in some cases have been leached out of the neighbouring strata and concentrated in specific ore-repositories, the difficulty still remains as to the genesis of the mineral in the rocks themselves, since these can be regarded only as a proximate source of the ore. Even the migration of the lead is not free from difficulty. The sulphide is rather a stable and sedentary mineral, whilst the sulphate is not markedly locomotive, and when formed by oxidation of the galena seems likely to remain near its original location. But though the sulphate of lead is only sparingly soluble in pure water, its solubility is increased by the presence of carbonic acid, whilst it is freely soluble, as shown by Doelter, in a solution of alkaline sulphide. It is possibly in the latter condition that it circulates through certain ore-bearing rocks.

Of late years there has been a great tendency to regard deposits of galena in limestone as having, in most cases, resulted from metasomatic action, that is to say, there has been molecular replacement of the rock by the ore. This view was advanced by Mr. F. S. Emmons in his masterly work on the great deposits of silver-lead ore at Leadville; \* and similar views have since been extended, with much acuteness by other observers, to explain the formation of galena-deposits in many other localities. Pseudomorphs showing the replacement of calcite by galena are, however, by no means common, but there is no doubt about the occurrence of such a change in the case of certain fossils. Thus, the late Mr. Townshend Hall recorded the occurrence of fossil corals mineralised with galena in Devonian rocks between Ilfracombe and Combe Martin.† The replacement of calcite by galena has been studied in microscopic sections of certain ore-bearing rocks, by Mr. W. Lindgren.‡

Roughly stated, it may be said that as the molecules of limestone were removed by solution their place was taken, without formation of spaces, by molecules of galena. Probably, however, it was not a simple case of simultaneous removal of one substance and precipitation of another, but rather a case involving complex chemical changes.

It has often been observed, and the observation holds true to some extent in the Northern lead-districts, that deposits of lead and zinc-ores are more common in limestones that are dolomitic than in those of normal type. Dolomite readily lends itself to metasomatic alteration, partly perhaps in consequence of its cavernous structure, for a free circulation of fluids through a rock is naturally favourable to its alteration. Permeable rocks admitting of ready percolation, or fissured rocks which offer conduits for the easy movement of liquids are just the rocks that may be expected to contain mineral matter, even though the solutions which traverse them

---

\* "Geology and Mining Industry of Leadville, Colorado." By Samuel Franklin Emmons. *Monographs U.S. Geol. Surv.*, vol. xii. (1886).

† "On the Association of Minerals and Fossils in North Devon." *Trans. Dev. Ass.*, vol. xxii. (1890), p. 166.

‡ "Metasomatic Processes in Fissure Veins." *Trans. Am. Inst. Min. Eng.*, vol. xxx (1901), p. 578.

are but dilute. The metal-bearing solution may flow through one channel, whilst the precipitant travels along another, and the commingling of the liquids may lead to deposition of ore. Bischof obtained crystals of galena by the protracted action of sulphuretted hydrogen on a very dilute solution of a lead salt.

In the opinion of Mr. J. G. Goodchild, who has an extensive acquaintance with the ore-deposits of Cumberland and Westmorland, the galena probably originated during the last upheaval of the district, when the volcanic agencies which had been so active in early Tertiary times were gradually waning, and were represented by numerous hot springs.\* Thermal waters rising from deep sources brought up metallic sulphides, which would be deposited when the heat was sufficiently lessened and the pressure reduced. He considers it likely that the lead-ore had originally a wide extension through the rocks in the form of a series of shallow disconnected deposits.

#### *Cerussite (Nos. 1188 to 1190).*

Carbonate of lead is the most common product of the alteration of galena, but the Alston district is not remarkable for crystals of this species. By the miner it is known as *white ore*, but though containing a large proportion of metal it was regarded by the early explorers as a sparry mineral of no value. Its formation is illustrated by such a specimen as No. 1188, from the Craven district in Yorkshire, where it surrounds a nucleus of the unaltered sulphide. Careful examination of similar specimens has sometimes revealed a thin layer of sulphate of lead beneath the carbonate, suggesting that the galena was first altered to sulphate and this converted to carbonate by reaction with the limestone matrix.

Since cerussite is a secondary mineral, due to epigenic action, it is not commonly found at great depths or in old mines. Crystals are occasionally found seated on galena as the parent mineral. The crystals are isomorphous with those of the carbonates of barium and strontium, and with carbonate of calcium in the state of aragonite.

#### *Blende (Nos. 1191 to 1202).*

The sulphide of zinc or *zinc-blende*, formerly despised under such names as "*mock ore*" and "*false lead*," has in recent years acquired considerable economic importance in the Northern mining districts (p. 162). In ore-deposits which contain both zinc and lead, like those of the North, it is a matter of common observation that galena may be found in the upper part of a vein, but that blende is not reached until the deeper parts are worked. In a mixed ore-body, the tendency seems to be for blende to increase in depth whilst galena diminishes. Such a relation has been explained by Professor Van Hise as due partly to the zinc-sulphide having been deposited

---

\* *Trans. Cumb. Assoc.*, Part vii. (1882), p. 107.



from ascending solutions lower down than the lead sulphide, and partly to a secondary concentration of zinc-sulphide by descending waters.\* Blende may be readily removed in a soluble form and re-deposited at lower levels, but galena is one of the last sulphides to go into solution.

Zinc is a metal very widely diffused in nature. Dieulafait found it in sea water, and it occurs in greater or less quantity in many sedimentary rocks, especially limestone. Crystals of blende are not uncommon in the fissures of nodules of clay ironstone, notably in those from the Coalbrookdale coal-field, as seen in Wall-case 24, and it occurs even in the casts of fossil shells (No. 1009). In the Cleveland iron-ore, an altered sedimentary deposit of the Middle Lias, zinc may be found, and Mr. J. Pattinson obtained considerable quantities of the oxide from the waste-gas tubes of blast-furnaces smelting this ore.† Oxide of zinc, in hexagonal prisms, has also been found in connection with the furnaces at Westbury-on-Severn, where iron ore from the Coral Rag was smelted. Mr. Fox-Strangways has pointed to the rather common occurrence of zinc-blende in the Lias, especially in the doggers in the upper part of the Lower Lias, where it is associated with organic remains.‡ Zinc blende has occasionally been found in old mine-timber.

In such cases the sulphide has probably been reduced by organic matter from the sulphate, a very soluble salt which itself has generally been formed from the oxidation of blende. In other cases the zinc may have been transported as a solution of carbonate, from which, on mingling with waters containing sulphuretted hydrogen, zinc sulphide would be precipitated.

Only a few specimens of zinc-blende are exhibited in this Case. Crystals of blende are associated with quartz in No. 1196; with calcite in No. 1194; with pearl-spar in Nos. 1195 and 1200; with chalybite in No. 1202; and with pyrite in No. 1197. In the specimen No. 1199, crystalline blende occurs as a large hemispherical mass, with radial structure, in association with deep purple fluor-spar and partly encrusted with pearl-spar. A similar specimen, from the old lead-mines of Allenheads, will be found in Wall-case No. 28.

#### *Calamine, etc. (Nos. 1203 to 1206).*

The characters of *Calamine*, or zinc carbonate, have already been noticed in connection with the specimens from Derbyshire in Case VIII. (p. 141). The representatives of this species from Alston Moor, coupled with some excellent examples from the same locality in Wall-case 33, serve to show the mineral in mammillary deposits, evidently thrown down from solution, rather like a zinciferous stalagmite. Sulphate of zinc, resulting from the oxidation of blende, if carried in solution through the limestone, would suffer decomposi-

---

\* "Some Principles Controlling the Deposition of Ores." By C. R. Van Hise. *Trans. Am. Inst. Min., Eng.*, vol. xxx. (1901), p. 27.

† *Rep. Brit. Assoc. for 1863*, p. 49.

‡ *Mem. Geol. Surv. Jurassic Rocks*, vol. I. Yorkshire, (1892), p. 473.

tion; during its percolation and in the presence of an excess of carbonate of lime, or under certain other conditions, the carbonate of zinc might be precipitated, whilst sulphate of lime would be carried away in solution.\* The calamine might thus either replace the limestone, as already mentioned (p. 141), or be deposited in free spaces, like a calcareous dripstone. No. 1204 shows the calamine in *stalactitic*, and No. 1205 in *stalagmitic* forms.

As small quantities of copper-ore occur in the limestone of the Northern lead-and-zinc districts, and have indeed been occasionally worked, it is easy to understand that carbonate of copper might enter into association with carbonate of zinc, with production of such a mineral as *Aurichalcite*. The specimen from Nenthead (No. 1206) may be compared with that from Roughten Gill (No. 1155, p. 158).

*Chalybite, Pyrite, etc. (Nos. 1207 to 1215).*

*Chalybite*, or *siderite*, is present in many of the ore-deposits of the Northern lead districts, often occurring in the sparry or crystalline state of *spathic iron-ore*, forming the mineral of the vein-stuff, or gangue, usually in a fault-breccia, and in many cases converted more or less completely into *limonite*. The fine spathose ore of Weardale recalls the similar ore of the Brendon Hills. It is, as is usually the case with such ores, manganiferous, and has been valued for the production of spiegeleisen and ferro-manganese. Mr. A. Dick remarks that the Weardale ore which he examined, on solution in hydrochloric acid, left a skeleton of quartz having the shape and size of the original mass.†

In No. 1209 cubes of purple fluor-spar are coated, on certain sides only, with an incrustation of the carbonate of iron in brown lenticular crystals. Other specimens of like character, but of larger size, will be found in Wall-case 30.

Chalybite is a mineral which appears to be of late introduction in the lead-veins of the Alston district, as pointed out by Sir W. W. Smyth. Its recent formation is illustrated by its occurrence as an incrustation on an iron rod in one of the mines.‡ Fossils have been found in which the calcareous parts were represented by carbonate of iron, and the mineral appears in many cases to have been formed by alteration of the limestone. Mr. J. G. Goodchild has suggested that the replacement has been effected by means of iron-bearing solutions filtering downwards from the New Red strata which at one time probably covered the Carboniferous rocks.§

A few specimens exhibited here represent the two types of iron disulphide—*pyrite*, the common cubic type (Nos. 1210 to 1212), and *marcasite*, the orthorhombic species (Nos. 1213 and 1214). A third species of iron sulphide called *Pyrrhotite*, or often *Pyrrhotine*,

\* See L. Hoffman in *Journ. f. Prakt. Geol.* Feb. 1896, p. 51.

† *Mem. Geol. Surv.* "The Iron-ores of Great Britain." Part i., 1856, p. 58.

‡ *Quart. Journ. Sc.*, vol. v., p. 36.

§ *Trans. Cumberland Assoc.*, vol. viii. (1883), p. 200.



is represented by No. 1215, a specimen from Smittergill Head. This species differs from the other sulphides of iron (1) in crystallizing in the hexagonal system, (2) in presenting a bronze colour, and (3) in possessing magnetic properties, whence it is often called *magnetic pyrites*.

*Barytes* (Nos. 1216 to 1234).

Some of the finest crystals of *Barytes*, or *Barite*, found anywhere in Britain have been obtained from the neighbourhood of Alston Moor, especially from Dufton Fell in Westmorland. It was this locality that yielded the huge crystal, weighing a hundredweight, which is placed in the Case beneath Section I. of the Horse-shoe Case. This specimen, believed to be the largest crystal of barytes ever recorded, was shown in the Great Exhibition of 1851. Some colourless pellucid crystals of similar type, probably from Silver-band, are exhibited in this Case (Nos. 1221, 1222).

Barytes crystallises in the orthorhombic system, and the crystals exhibit much variation of habit, being frequently prismatic by extension in the direction of one or other of the axes. Tabular crystals are common. The specimen No. 1225 is a cleavage-fragment, the mineral giving perfect cleavage parallel to what is regarded by some as the basal pinacoid, by others as the brachypinacoid, and less perfect cleavage in two other rectangular directions. The rainbow-coloured bands in Nos. 1217 to 1219 are an optical effect, due to the narrow cleavage cracks in the specimens giving the interference-tints of thin plates.

Crystals of barytes often resemble those of celestite, the sulphates of the closely related metals, barium and strontium, being isomorphous. The relation of barium to lead is also in many ways very intimate—closer indeed than its relation to calcium. This is illustrated by the isomorphism of the sulphates and carbonates—barytes being isomorphous with anglesite, and witherite with cerussite. On the contrary the relation of barytes to anhydrite, or calcium sulphate, though the latter is also orthorhombic, is much less marked. A small proportion of strontium and calcium sulphate may be present in barytes.

In the Northern lead veins, as in those of Derbyshire (p. 136), the barytes frequently appears in the form of *cawk*, a variety which is either earthy or is in opaque white curved lamellæ. The rounded groups of tabular crystals are sometimes called *crested* or *cock's-comb barytes* (No. 1230). A curious habit is exemplified by No. 1224, in which tabular crystals are disposed in a divergent group, like the partly-opened leaves of a book. The well-known *chisel-edged* crystals, from Alston Moor, are illustrated by No. 1223. In consequence of its high density, for a sparry mineral, barytes is often known as *heavy spar* (specific gravity 4·3 to 4·5).

As far back as 1851 Dieulafait called attention to the wide distribution of barium and strontium; and in recent years these elements have been recorded as occurring in a great number of rocks

and in many natural waters. According to Mr. F. W. Clarke and Dr. Hillebrand, barium forms about 0·03 to 0·04 per cent. of the crust of the earth.\* A large number of analyses, showing how widely barium is disseminated through rocks, have been collected by R. Delkeskamp.†

Since many igneous rocks contain barium, especially in their felspathic constituents, it has often been held that the barytes of certain mineral-veins may have been derived from the minerals of the neighbouring rocks. It was shown, for instance, by Sandberger that the veins of barytes in the granite of the Black Forest became thicker and more abundant in proportion as the felspar of the granite was richer in barium, whilst similar veins were even better developed in the gneiss of the district, in which the felspar contained as much as 0·81 per cent. of barium.

It has been observed that barytes tends to become localised in the upper part of many mineral deposits and to disappear in depth. Possibly in such cases oxidising influences may have converted barium sulphide into the insoluble sulphate. In other cases, barytes may have been precipitated by the action of soluble sulphates, like that of iron resulting from the decomposition of pyrites, on certain barium minerals in the neighbouring rocks.

Considering the extreme insolubility of sulphate of barium, it is interesting to cite a case, to which Mr. Goodchild has called attention,‡ in which crystals of barytes from Dufton had been invested by calcite, and then removed, leaving the calcite-crust cavity empty. It would seem then that the calcite, generally so easy of solubility, has withstood the attack of some solvent potent enough to carry off the intractable barytes. Several specimens here show the association of barytes with calcite (Nos. 1230 to 1234).

Some remarkable instances of the occurrence of barium salts in natural waters will be referred to in connection with the barium-bearing sandstones of the Trias (p. 187).

\* *Bull. U.S. Geol. Surv.*, No. 148, 1897, p. 13.

† "Die weite Verbreitung des Baryums in Gesteinen und Mineralquellen und die sich hieraus ergebenden Beweismittel für die Anwendbarkeit der Lateralsecretions- und Thermaltheorie auf die Genesis der Schwerspathgänge." *Zeits. f. Prakt. Geolog.*, April 1902, p. 117.

‡ *Trans. Cumb. Assoc.*, vol. viii. (1883), p. 196.



## CASE X.

## DIVISION 1.

## MINERALS OF THE NORTHERN LEAD DISTRICTS.

## SPARS OTHER THAN HEAVY SPAR.

*Witherite* (Nos. 1235 to 1246).

Although barium most commonly occurs in nature as a sulphate, it is also found not infrequently in the condition of a carbonate. Some excellent specimens of the crystallised carbonate, from Cumberland and Northumberland, are here exhibited. So far from being a mineral of only scientific interest, carbonate of barium is a substance of considerable economic value, occurring in rather extensive deposits and finding application in several ways in the industrial arts. During the year 1902 as much as 6,142 tons, valued at £12,284, were raised in Northumberland.

Barium carbonate was first recognised as distinct from barytes by Dr. W. Withering,\* who examined it chemically more than a century ago, and described it, according to the chemical language of his day, as *terra ponderosa aerata*, or "aerated barytes." In his honour the mineral was named *Witherite* by Werner. It crystallises in the orthorhombic system, and is isomorphous with aragonite, strontianite, and cerussite, these four species constituting a group characterised by similarity of crystalline form, of cleavage, and of optical properties.† A rather large and fine series of witherite crystals is here exhibited.

Crystals of witherite usually have a pyramidal habit, and the pyramids are often pseudo-hexagonal, so that the aspect of the mineral is rather suggestive of that of quartz. These hexagonal bi-pyramids are not simple crystals, but are really triplets, and their complex structure is revealed on section. The faces are often rough, with horizontal striations, and may carry a thin coating of opaque white barytes. Bischof showed that if water holding sulphate of calcium in solution passed over witherite it would give rise to sulphate of barium and carbonate of calcium. Solutions of other sulphates produce similar reactions. Hence it often happens that barium-bearing deposits carry the sulphate above, where superficial waters have been at play, and the carbonate below.

\* "Experiments and Observations on the Terra Ponderosa, etc." By William Withering. *Phil. Trans.*, vol. lxxiv. (1784), p. 293.

† See Table showing the relationship in Tschermak's *Lehrbuch der Mineralogie*, 4 ed., 1894, p. 259.

Witherite appears to have been first discovered by James Watt at Anglezark Moor, near Chorley, in Lancashire. Here the lode, running through the Kinderscout Grit (Millstone Grit) yields galena, blende, and copper-pyrites. Witherite is also found at Alston Moor, but the chief localities are Fallowfield Mine, near Hexham, in Northumberland, and Settlingstones in the same county; the last named is at present the most extensive producer of the mineral.

Like all barium salts, witherite is poisonous. Fowls have frequently been killed in the neighbourhood of the mines by picking up fragments of the mineral. It is a constituent of certain rat-poisons, and is employed as a source of various preparations of barium. Witherite has also been extensively used in sugar-refining, but owing to its poisonous character it has been displaced to a large extent by strontium carbonate. Glass-making is another industry in which witherite has found limited application. Josiah Wedgwood employed it in the manufacture of his delicate 'jasper ware.'

*Bromlite and Barytocalcite (Nos. 1247 to 1254).*

As far back as 1837 the name *Bromlite* was given by Dr. T. Thomson to a mineral from Bromley Hill, near Alston,\* but this name was set aside by many writers in favour of the term *Alstonite*. Recent regard for priority has, however, led to the revival of the older term.

The mineral called bromlite or alstonite, whilst commonly regarded as a double carbonate of barium and calcium, seems to be an isomorphous mixture of the two salts. Although belonging to the orthorhombic system, its crystals are usually small acute bi-pyramids of hexagonal habit, somewhat resembling those of witherite. In some specimens, the crystals have a slight pinkish tint, perhaps due to a trace of manganese. Strontium carbonate is recorded in some of the analyses.

Another mineral of similar composition is known as *Barytocalcite*—a name given to it by Mr. H. J. Brooke in 1824 (*Ann. Phil.*, vol. viii., p. 114), but as this crystallises in the monoclinic system, it is difficult to see how it can be brought into direct relationship with either the calcite group or the aragonite-witherite group of minerals. The crystals of barytocalcite commonly have a prismatic habit, and are disposed in divergent groups. In some cases they bear a superficial coating of barytes.

According to Analyses by A. Becker,† barytocalcite seems to be a definite molecular compound, conforming to the formula  $\text{BaCO}_3.\text{CaCO}_3$ , thus differing essentially from bromlite. Such a view indeed had previously been expressed by Prof. Groth.‡

\* *Phil. Mag.*, vol. xi. (1837), p. 45, see also *ibid.*, vol. vi. (1835), p. 1; and vol. x. (1837), p. 373.

† "Ueber die chemische Zusammensetzung des Barytocalcits und des Alstonits." *Zeits. f. Kryst.*, vol. xii. (1887), p. 222.

‡ "Tabellarische Uebersicht."



Both bromlite and baryto-calcite are minerals of very local distribution, being confined to Alston Moor and the neighbourhood of Hexham. Some of the finest examples of bromlite have been yielded by the Fallowfield Mine, near Hexham, which is famous for its witherite.

*Calcite and Aragonite (Nos. 1255 to 1312.)*

A rather extensive series of specimens illustrates the varieties of form and other physical characters presented by the *Calcite* of the Northern lead-mining districts. Calcite is a species unparalleled for its wealth of crystalline forms. Count de Bournon, in the early part of the nineteenth century, recognised several hundred modifications; \* and in recent years the crystallography of the species has been the subject of exhaustive study by several observers. Mr. J. R. Irby in 1878 recorded no fewer than fifty rhombohedra and 155 scalenohedra.†

Many of the Cumberland specimens here exhibited recall the calcites from the lead-bearing limestones of Derbyshire displayed in Case VII. (p. 132), but a comparison of the two collections nevertheless reveals considerable difference in the facies or general appearance of the groups. A casual glance is sufficient to suggest that whereas, broadly speaking, scalenohedra dominate in Derbyshire, the Alston specimens show a prevalence of obtuse rhombohedra constituting what is known as the "nail-headed" type of calcite.

The cause of the differences in the habit of the calcite crystals is not easy to explain, but it seems connected with the conditions under which crystallisation occurred, especially with the character of the solution from which the substance crystallised. Some interesting researches have been carried out in recent years by Heinrich Vater ‡ with the view of throwing light on this obscure subject. He concludes that from a pure solution in water, calcium carbonate crystallises in the fundamental rhombohedron, and that the occurrence of other forms is referable to the presence of co-solutes, that is to say, other substances in the solution from which crystallisation is effected. Sulphates were found to exert considerable influence, and sulphate of sodium so modified the calcite crystals that they assumed the form of hexagonal prisms with rhombohedral terminations. The influence of the co-solute seemed to increase when the crystallisation took place, as it probably does usually in nature, very slowly.

Although no specimens of crystallised *Aragonite* are exhibited among the Alston minerals, there is a fair example of that particular variety which is known, rather strangely, as *flos ferri*,

\* "Traité de Minéralogie." Première Partie. 3 vols. London, 1808.

† "On the Crystallography of Calcite." Inaugural Dissertation. Bonn. 1878. Dr. Irby died in 1880.

‡ An excellent summary of Vater's papers, by Dr. A. Hutchinson, will be found in the *Min. Mag.* for Dec., 1903, p. 692. The originals appeared in the *Zeits. f. Kryst.*, from 1893 to 1899.

or *iron-bloom* (No. 1307). This form of aragonite occurs as arborescent masses, with interlacing stems and branches, fibrous in structure, and snow-white or creamy in colour. From the resemblance of some of these white sprigs to certain kinds of coral, the form is recognised as "coralloidal." Though called "flower of iron," the Cumberland mineral occurs not in iron-mines but in cavities in the limestone near to the veins of lead-ore, and it was formerly rather abundant at the Dufton Mines. The conditions of its occurrence were studied many years ago by Mr. W. Wallace,\* who suggested that the growth of the mineral was due to a circulation of fluids through its pores. It occurs only above water-level, where the conditions are favourable for the precipitation of carbonate of lime, and the formation of stalactitic and stalagmitic deposits.

Fibrous forms of carbonate of lime are known from the lustre which they display, especially when polished, as "*satin-spar*"—a name which is applied, however, to several fibrous minerals, including calcite, aragonite, and gypsum. Nos. 1305 and 1306 are excellent examples of satin-spar from Alston Moor; the latter specimen, which is polished, illustrating the occurrence of the mineral as veins in black shale. It is often assumed that such fibrous carbonate of lime is necessarily aragonite, but Mr. L. J. Spencer has shown by optical examination of the Alston spar, as also by its density, that it is really composed of calcite, each fibre being a crystal of calcite enormously elongated in the direction of a rhombohedron edge.† It has been shown, moreover, by Dr. G. P. Merrill that most of the stalagmitic carbonate of lime known as *onyx marble* is not aragonite, as is frequently supposed, but really calcite.‡

The specimen No. 1309 shows delicate pearly scales of carbonate of lime, such as is known to German mineralogists as *Schaumkalk*. It is often regarded as an alteration-product, due to the conversion of gypsum into a carbonate, like aragonite.

A few specimens exhibited here (Nos. 1310 to 1312) illustrate the occurrence of *Dolomite*, or *pearl-spar*, among the minerals of the lead deposits of Cumberland. The characteristic specimen No. 1310 shows the spar in a crowded group of small cream-coloured rhombohedral crystals, with curved faces and nacreous lustre, seated on galena. In No. 1311 there is a similar aggregate of curved or saddle-shaped crystals, upon which calcite has crystallised in a linear group of obtuse rhombohedra.§

---

\* "On the Growth of *Flos Ferri*, or Coralloidal Arragonite." *Quart. Journ. Geol. Soc.*, vol. xxi. (1865), p. 413.

† "The 'Satin-spar' of Alston in Cumberland; and the Determination of massive and fibrous Calcites and Aragonites." *Min. Mag.*, vol. xi. (1897), p. 184.

‡ *Smithsonian Report (U.S. Nat. Mus.)* for 1893-4, p. 539.

§ On the subject of dolomitisation see Prof. Judd's researches in Report of the Coral-Reef Committee of the Royal Society, Section xii. 1904. See also Dr. Skeats in *Bull. Harvard Coll.*, xlii.; geol. series, vol. vi., No. 2, 1903.



## DIVISION 2.

## MINERALS OF THE NORTHERN LEAD DISTRICTS, ETC.

## THE SPARS, CONTINUED.

*Fluorite* (Nos. 1313 to 1352).

Some of the finest known crystals of *Fluorite* have been obtained from the Northern lead-mining districts, especially from the mines of Weardale in Durham. A rather large series of representative specimens is here exhibited, including many crystals which rival the fluors already described from Derbyshire, Cornwall, and Devon (pp. 85, 134).

The Northern fluors are generally crystallised in simple cubes, which in most cases are boldly and symmetrically developed. Occasionally, however, the cube is extended along one axis, so that some of the faces become long rectangles: such a parallelopipedon is well seen in No. 1313—which is a specimen of purple fluor from Weardale in Durham, with small crystals of calcareous spar perched upon the faces of the larger crystal.

Several of the specimens show the characteristic interpenetration of two cubes. The three-faced solid angles of one cube are seen jutting out from the faces of the other, in such specimens as Nos. 1314 to 1316. In these penetration-twins it would be possible to bring one of the cubes into the position of the other by giving it half a complete turn, or rotating it through  $180^\circ$ , round an axis running from one quoin of the cube diagonally to the opposite quoin: in other words, the twin axis is a cube-diagonal, or a normal to the plane of an octahedron.

Considerable diversity of colour is presented by the specimens of fluorite here exhibited. Some of the finest Alston and Weardale fluors are of violet or purple colour (Nos. 1314 to 1320), whilst those from Weardale are often of green tints (Nos. 1323 to 1328). Many years ago Wyruboff referred the colour of many fluors to the presence of organic matter, and thus explained the tinctorial change which the mineral not uncommonly suffers when heated.\* The pigment in some cases is certainly fugitive. More recently the studies of K. v. Kraatz-Koschlau and Lothar Wöhler have supported Wyruboff's views. They found in a violet fluorspar from Weardale 0.01 per cent. of carbon and 0.008 of hydrogen, in blue and green fluors from Cumberland 0.009 of carbon and 0.002 of hydrogen, and in yellow fluor from Durham 0.007 of carbon and 0.0025 of hydrogen; whilst the colourless fluor was free from either of these elements.† The organic nature of the colouring agent

\* "Sur les Substances Colorantes des Fluorines." *Bull. Soc. Chim.*, vol. v. (1866), p. 334.

† "Die Natürlichen Färbungen der Mineralien." *Min. Mit.*, vol. xviii (1899), pp. 304, 447.

has been denied by E. Weinschenk, who holds that the presence of a hydrocarbon in the fluor does not necessarily prove that the hydrocarbon is responsible for the colour.\*

Some of the Cumberland fluorite is remarkable for its beautiful *fluorescence*. Whilst the mineral may appear violet or purple or bluish by reflected light, it becomes pale green when viewed by transmitted illumination. The phenomenon of fluorescence was so named by Stokes in consequence of its exhibition by this mineral. Now that the existence of certain hydrocarbons in fluor is recognised, it has been suggested that the fluorescence may be connected with their presence, since it is well known that fluorescence is strikingly exhibited by certain substances of this nature, such as petroleum, and by ozocerite and some kinds of amber, like the Sicilian simetite.

The phosphorescence of fluorspar has been noticed in connection with the Cornish specimens (p. 88). The Cumberland fluor is in certain cases markedly thermophosphorescent. It may be added that fluorite is found to phosphoresce under the influence of the Röntgen rays.

Some of the green cubes of fluorite from Weardale are remarkable for enclosing cavities holding liquid, with a vapour-bubble, movable like that of a spirit-level. According to Greg and Lettsom, these liquid drops are most frequent in cubes which have a dull greasy look, especially in such crystals as have the edges bevelled. Paper arrows indicate the position of the moving bubble in the specimens in the tray No. 1324.

So much has already been said with reference to fluorspar that little need now be added. The specimens in this compartment may serve to illustrate the characteristic associations of the mineral in the ore-deposits of the country near Alston. The fluorite is associated with *calcite* in No. 1351, with *barytes* in No. 1339, with *quartz* in No. 1354, with *galena* in No. 1340, with *blende* in No. 1342, and with *chalybite* in Nos. 1343 to 1348. An interesting formation is represented by the specimen No. 1352, in which fluorspar, crystallising in an aggregate of pale purple cubes, is coated on certain faces only with quartz, upon which there is a sprinkling of minute crystals of chalcopyrite. In No. 1353 the cubes of fluor are extended along one axis, and are coated with minute crystals of quartz, forming a drusy surface.

In No. 1349 the following succession may be noted: (1) fluorite in large violet cubes; (2) galena, in cubo-octahedra built up by the confused aggregation of sub-individuals; (3) calcite in low rhombohedral crystals. Here the fluorspar is of earlier formation than the galena, but in other cases, as in No. 1328, the fluor may be of later growth.

It is well known that calcium fluoride is slightly soluble in water containing acid carbonate of calcium. It is, however, soluble to an appreciable extent even in pure water. According to Kohlrausch

---

† "Natürlich Färbungen der Mineralien." *Min. Mitt.*, vol. xix. (1900), p. 144.



and Rose, who determined the solubility by the electric conductivity of the solution, fourteen milligrams of fluorspar were dissolved in a litre of water at 15° C\*. It is, in fact, more soluble in pure water than calcite. Hence it is not difficult to understand how it comes about that many natural waters contain fluorine as a calcium compound, and that fluorite may migrate in mineral deposits, and be precipitated at different stages in the history of vein-formation.

Fluorspar occurs in such abundance as a vein-stone in the lead districts of the North of England that it is worked on a commercial scale. In the year 1902 the county of Durham yielded as much as 3,708 tons of spar, valued at £1,417.† This was raised in the neighbourhood of Stanhope in Weardale. The economic uses of fluorspar have been mentioned in the notice of the Derbyshire minerals (p. 135).

So prolific are the mineral deposits of the Northern lead districts in fine examples of fluorspar that in addition to the large series shown here, other specimens from the same localities, including some larger pieces, will be found by the visitor in the Ludlam Collection displayed in the Hall and in Section M of the Horse-shoe Case.

#### *Quartz (Nos. 1353 to 1360).*

Whilst fluorspar, barytes, and calcite are the principal gangue-minerals in the lead-lodes of the Northern counties, *Quartz* also is occasionally found in the vein-stuff of certain deposits. On the eastern side of the Hall of the Museum, the visitor will find a pedestal supporting a huge mass of well-crystallised white quartz from the lead mines of Weardale in Durham—an imposing specimen, which was shown, as an exceptional example of this mineral, in the Great Exhibition of 1851.

Only a few specimens of quartz are here exhibited, and these are not to be compared for beauty with the crystals from the hæmatite deposits of West Cumberland, displayed in Case VIII. (p. 148). In the fluor-bearing veins, the quartz has evidently been formed at different stages in the history of the deposits. Thus, in No. 1354 the quartz is well crystallised in six-sided pyramids, and upon these crystals some beautiful cubes of fluorite, remarkable for their delicate purple tint, have been deposited. On the other hand, No. 1355 shows a growth of pellucid crystals of quartz on cubes of yellow fluor. In the former specimen, then, the formation of the quartz was anterior, and in the latter posterior, to that of the fluorspar. Nor are these cases exceptional. The examination of other specimens in the collection will show that in some cases the quartz forms the seat of the fluor, and in other cases encrusts it. So too with the galena. Quartz

---

\* F. Kohlrausch and F. Rose in *Zeits. f. Phy. Ch.*, vol. xii. (1893), p. 162. Quoted in Braun's "Chemische Mineralogie," 1896, p. 397.

† Home Office Report on Mines and Quarries for 1902. Edited by Sir C. Le Neve Foster, F.R.S., p. 209.

crystals may support a deposit of lead-ore, as in No. 1354, or a growth of quartz may have occurred on the ore, as in No. 1357. Successive generations of quartz crystals may be observed on such a specimen as No. 1355, where quartz has preceded and also succeeded the formation of fluorspar.

Very curious is the *Cellular quartz* from Teesdale, specimens of which are to be found in most mineral collections. It is illustrated here by No. 1359, and another and larger specimen will be found in the Horse-shoe Case. This brownish quartz forms an open honey-combed structure, probably representing the siliceous septa of what was once a septarium. Most septaria are composed of argillaceous limestone, or of clay ironstone, which by contracting on solidification, becomes fissured, and the cracks so formed are either left open or are filled in, more or less completely, by deposits of calcite, forming radiating or reticulated septa. The crystalline calcite is usually more durable than the substance of the nodule, and, therefore, on weathering, the septa stand out in relief. In the flat nodule from which such a specimen as No. 1359 has been derived, the shrinkage-fissures, formed with great regularity, must have been filled with a siliceous deposit, which has been left, as a kind of skeleton, after the entire removal of the substance of the original septarium.

The small isolated crystals of quartz from Harrogate, No. 1360, recall the similar crystals known as "Buxton diamonds," noticed on p. 136.

#### MINERALS OF SHROPSHIRE.

(Nos. 1361 to 1368.)

In the Shelve district—a tract of wild country in Shropshire, near the Welsh border, consisting of rocks of Lower Silurian (Ordovician) age—lead-ore has been worked from a very remote period. Roman pigs of lead, found at, or near, the mine called Roman Gravels, carry back the industry of the district to at least the second century of our era. At the present time, however, there is but little activity in connection with the metal mines of the county. In 1902 only 805 tons of lead-ore were raised in Shropshire, and this was yielded almost entirely by one mine—the Snailbeach near Minsterley. This mine produced also 378 tons of zinc-ore.

The lead-lodes of this district vary much in direction, but many of them strike a little N. of west, and S. of east. They generally run through dark slaty rocks associated with sandstones and shales, and invaded by igneous intrusions. Many of the veinstones are brecciated, consisting of fragments of the neighbouring rock cemented by calcite, barytes and quartz. The ore generally occurs in "shoots," or inclined bands, and consists of galena, blende and pyrites.

As the veins are not productive of many crystallised minerals, the collection here exhibited is rather meagre. It includes samples of the typical *Galena* from Snailbeach (No. 1361) and of *Cerussite*, in fine acicular crystals (No. 1362). The Salopian lead ore is not usually argentiferous. Among the sparry minerals of the veinstone may be mentioned the Snailbeach *Calcite* and several specimens of



*Barytes*. Some beautifully pellucid crystals of barytes from the East Wotherton Mine, near Minsterley, presented by A. Steven, Esq., are here exhibited (No. 1367). They rather resemble some of the crystals from Dufton. The Salopian barytes has been examined crystallographically by Prof. Miers \* and by Mr. C. J. Woodward.†

The specimen No. 1366 is an example of barytes from Snailbeach, remarkable for its brick red colour, due to the presence of iron oxide. When barytes is used as a white pigment every trace of iron has to be removed—the removal being effected by boiling with dilute hydrochloric acid.

Associated with the barytes of Shropshire, *Witherite* occasionally occurs, as described by Mr. Aikin in the early part of the last century‡. According to this observer, it was found in irregular masses, often of considerable size, embedded in the barytes, and was called by the miners “yellow spar,” because though appearing white by reflected light, it became yellow by transmitted light. A specimen of the fibrous witherite is here exhibited (No. 1368).

No. 1365 is an example of *Asphalt*, associated with calcite, from the Pennerley lead mine, near Shelve. Bituminous minerals are occasionally found in rock-fissures not only in the Shelve district and in the Stiperstones, but in the yet older slaty rocks of the Longmynd, regarded as pre-Cambrian. The late Dr. Ricketts believed that these carbonaceous minerals were probably derived from the Coal measures.§

#### MINERALS OF LEICESTERSHIRE.

(Nos. 1369 to 1380.)

The collection contains a few specimens from the mines which were at one time worked near Ashby-de-la-Zouch, in Leicestershire. These include some examples of *Calcite*, crystallised in sharply defined scalenohedra, much like the dog-tooth spar of Derbyshire, and probably formed under similar conditions. The calcareous spar is associated in some of the specimens with *Galena* (No. 1371) and in others with *Chalcopyrite* (Nos. 1372, 1376). In some cases the copper-pyrites is sprinkled over the calcite, rather recalling the association seen in certain specimens from Ecton.

Professor Hull remarks that the Carboniferous Limestone of Dimmingsdale is highly metalliferous, and records the occurrence, in one of the veins, of copper-pyrites, galena, calcareous spar, sparry iron ore, blende and bitumen.|| According to Prof. Bauerman, whom he cites, the lodes are mostly brecciated, and the galena generally occurs in ribs at each side of the walls, whilst the other minerals are found crystallised in druses of the veinstone.

\* “Nature,” vol. xxix. (1883), pp. 29, 124.

† *Ibid.*, p. 77.

‡ “Notice concerning the Shropshire Witherite.” *Trans. Geol. Soc.*, vol. iv. (1811), p. 438.

§ “On Bitumen in the Palæozoic Rocks of Shropshire.” *Proc. Liverpool Geol. Soc.*, 1885. For minerals of Shelve see G. H. Morton, *ibid.*, 1869.

|| *Mem. Geol. Surv.* “The Geology of the Leicestershire Coal-field,” 1860, p. 16.

The specimen No. 1377 is a good example of the occurrence of *Asphalt* at Staunton Harold, near Ashby-de-la-Zouch. Bituminous minerals, in some cases solid and in others liquid, are not uncommon in the cavities in the older fossiliferous limestones. The next specimen, No. 1378, is interesting as showing a bituminous substance, associated with calcite, which has crystallised in the joints of the granite of Mount Sorrel, near Loughborough.

Another specimen from Mount Sorrel (No. 1379) illustrates the occurrence of the rather rare mineral *Molybdenite*, or sulphide of molybdenum, in the characteristic form of graphite-like crystalline plates, on the walls of joints in the granite. This specimen was presented by Sir C. Le Neve Foster, who first called attention to the occurrence of the mineral at this locality,\* where it was regarded by the quarrymen as "lead." The same species occurs in the Shap granite, as remarked on p. 154.

The county of Warwick has furnished the specimen of the mineral called after the classical name of the locality, *Varviscite*, and exhibited here as No. 1380. This mineral was found in the deposits of manganese ore which were formerly worked in the Cambrian rocks of Hartshill. The name was given by Mr. Richard Phillips, on the assumption that the mineral was a distinct species, but it is now usually held to be merely a mixture of pyrolusite and manganite. Mr. Phillips (b. 1778, d. 1851) was the first Curator of this Museum.

---

\* "On the Occurrence of Molybdenite in Leicestershire, etc." *Geol. Mag.*, vol. iii. (1866) p. 525.



## CASE XI.

## DIVISION 1.

## MINERALS OF THE NEOZOIC STRATA.

CHIEFLY FROM THE MIDLANDS AND S.E. ENGLAND.

(Nos. 1381 to 1448.)

So far as Southern Britain is concerned, the principal mineral districts are fairly represented—though with many gaps—in the contents of the ten preceding Cases. The remaining minerals of England find representation in that part of the Collection now to be noticed, which is placed in the first half of Case XI.

Most of the mineral deposits of Britain occur in connection with the Palæozoic strata, or even with rocks still more ancient. The minerals to be now described occur, on the contrary, in Neozoic strata, that is, in the Secondary and Tertiary formations. With the exception of the iron-ores, and a few other minerals, they are not generally regarded as metalliferous. As a rule they are found in bedded deposits rather than in veins, and are not usually so well crystallised as the vein-minerals, though occasional exceptions may be cited, notably in the case of gypsum. A few of these minerals have already been noticed; thus, some of the products of the Trias have naturally enough taken their place among the minerals of the Bristol district. But these are exceptional. Most of the minerals previously described have been derived from deposits in the older rocks, though it by no means follows that the formation of the mineral itself is of equal antiquity with that of the rock in which it occurs. The rock may belong to one period; the deposit which it encloses to quite another. It has been already remarked, for example, that certain mineral deposits in the Carboniferous rocks may be of Tertiary age. In the case, however, of many of the minerals which occur in the later sedimentary rocks, it is probable that they were contemporaneous, or nearly contemporaneous, with the rock which acts as the matrix.

In the arrangement of the Neozoic minerals, a strictly topographical arrangement has not been adhered to, since it would naturally have led to much repetition of description, where a common species, like gypsum, occurs in many localities at several distinct horizons. A conveniently elastic arrangement has therefore been followed—partly stratigraphical, partly mineralogical, but without pretence to scientific precision.

*Halite or Rock-salt (Nos. 1381 to 1383).*

At the base of the Neozoic strata, according to ordinary classification, stands the Trias, and of all the minerals yielded by the Trias of this country the most important is *Rock-salt*, or, as it is generally termed by modern mineralogists, *Halite*. Extensive deposits of this mineral occur near the base of the Keuper Marl. It usually forms lenticular beds, varying in thickness from a few inches to upwards of 100 feet. In some parts of Cheshire the rock-salt is mined, but in most salt-works the substance is obtained from brine, which has dissolved the salt from the saliferous marl. In consequence of the abundance of salt the New Red Sandstone was termed by the early geologists the "Saliferous system." Although salt in this country is practically limited to the Triassic and perhaps Permian strata, important deposits occur in other parts of the world at various geological horizons, some of the most notable Continental deposits being of Tertiary age.\*

Pure halite, as seen in No. 1381, is a colourless pellucid mineral, crystallising in the cubic system, and presenting perfect cubic cleavage. Usually, however, it is coloured more or less deeply, as exemplified by the brown specimen No. 1382, the colour being here referable to mechanical association with oxide of iron—a substance very widely distributed throughout the Triassic strata.

The salt may be regarded as contemporaneous with the Keuper marl in which it occurs, and it has no doubt been deposited by the evaporation of salt water. Possibly an arm of the sea may have been cut off so as to become almost land-locked, as in the case of the Kara Boghaz, or "Black Gulf"—a great sheet of water on the eastern side of the Caspian, almost separated by a sand barrier from the general body of water, and forming around its margin a kind of natural salt-pan. It seems more likely, however, that in most cases the salt was deposited in areas of inland drainage, where the waters, destitute of any outlet, would become concentrated whenever the quantity lost by evaporation greatly exceeded the supply of fresh water. The Great Salt Lake of Utah and the Dead Sea are known to have shrunk in volume from this cause, so that the water has gradually become more and more saline.† Such inland sheets of salt water probably present a parallel, as suggested by Sir A. C. Ramsay, to the lakes in which the rock-salt was deposited.‡ On the whole, the physical conditions of the British area during the period of salt formation in the New Red Sandstone age may have

\* See Sir A. C. Ramsay's Presidential Address to the British Association at Swansea (1880): "Salt and Salt-lakes," p. 9.

† *U. S. Geol. Surv. Mon.*, No. I. By G. K. Gilbert, 1890; and No. XI. by I. C. Russell, 1885.

‡ "The Physical Geology and Geography of Great Britain." By the late Sir A. C. Ramsay, LL.D., F.R.S., 6th Ed. by H. B. Woodward, F.R.S., 1894, p. 128. Also Ramsay's paper "On the Physical Relations of the New Red Marl," etc. *Quart. Journ. Geol. Soc.*, vol. xxvii. (1871), p. 189.



been not dissimilar to the conditions which obtain at the present time in such countries as Central Asia, where salt lakes occur in a comparatively rainless or desert region.

Cubic cavities in certain rocks attest the former presence of crystals of salt, and in many cases such cavities have been filled in with mud and other mineral matter so as to form natural casts in the cubic moulds. Pseudomorphous crystals of this character are shown in the specimen No. 1383 from the Keuper marls of Cheshire.

Rock-salt is worked to a limited extent in Cheshire and Lancashire, but the amount yielded in 1902 was only 129,664 tons. On the other hand, the salt obtained from brine springs in England, whether natural or artificial, including the salt contained in the brine run direct from the wells to the alkali works, amounted in the same year to as much as 1,719,625 tons. These brine springs are situated in Cheshire, Staffordshire, Worcestershire, Lancashire, Yorkshire, and Durham.\*

With regard to the age of the salt deposits of North-East Yorkshire and South Durham, discovered about forty years ago by borings in the Tees valley, there is some difference of opinion, since certain authorities regard them as Permian, whilst others hold them to be of Triassic age.†

#### *Gypsum* (Nos. 1384 to 1399).

In association with the rock-salt of the New Red Sandstone, *Gypsum* is almost invariably found. Although gypsum frequently occurs elsewhere unaccompanied by salt, the salt is rarely found without gypsum, and such a relationship must be more than accidental. If sea-water be evaporated under the microscope, it is seen that acicular crystals of gypsum are first formed, and then followed by little cubes of salt. Fractional crystallisation of a similar nature occurs in salterns and salt-gardens, where there is always a tendency for the sparingly soluble gypsum to be deposited before the chloride of sodium. It is believed, however, that the deposition of gypsum in marine lagoons may be partly due to the action of certain bacteria.‡

Much of the Triassic gypsum occurs in the crystallo-granular form of *Alabaster*—a material extensively used for internal ornamental sculpture, especially in ecclesiastical architecture. Being so soft as to be scratched even by the finger-nail, it is readily wrought into elaborate forms, whilst the associated oxide of iron produces on the polished face of the stone a pleasing effect by its veins and

---

\* Home Office Report, Mines and Quarries, for 1902, p. 264.

† "On the Stratigraphical Position of the Salt-measures of South Durham." By Prof. G. A. Lebour. *Rep. Brit. Assoc. for 1886* (Birmingham), p. 673. "On the Durham Salt District." By E. Wilson. *Quart. Journ. Geol. Soc.*, vol. xlv. (1888), p. 761. "The Cleveland and S. Durham Salt Industry." By John Marley. *Trans. Fed. Inst. Min. Eng.*, vol. i. (1892), p. 339.

‡ C. Barrois. *Ann. Soc. Géol. Nord.*, vol. xxvi. (1897), p. 19.

cloudings. Many examples of carved alabaster are exhibited in the Hall; and the walls of the Vestibule of the Museum are lined with slabs of this decorative stone.

The gypseous marls of the Trias have been largely worked for sake of the alabaster at Fauld in Staffordshire, at Chellaston in Derbyshire, and at Newark in Nottinghamshire. According to Mr. Metcalfe the mineral occurs in thick, nodular beds or "floors," in small lenticular masses or "cakes," and in globular or spheroidal masses called "balls" or "bowls."\* The granular gypsum may be snow-white (No. 1385), or dull grey (No. 1386), or pink (Nos. 1387, 1388). Some of these specimens are from Triassic marls at Watchet on the north coast of Somersetshire, and others from the neighbourhood of Penarth, south of Cardiff.

In certain veins running through the gypseous marls the mineral occasionally occurs in a fibrous form, and is then known as *Satin-Spar*—a name applied also to fibrous calcite, as already explained (p. 173). Some examples of fibrous gypsum, mostly from East Bridgford, in Nottinghamshire, are exhibited here (Nos. 1389-1390), whilst others, illustrating its aspect when cut and polished, are shown in Section H of the Horse-shoe Case. Like all substances composed of parallel fibres, the spar, when cut with a convex surface, exhibits a luminous band running at right angles to the direction of the fibres. The beads in the Horse-shoe Case illustrate this appearance. A curiously foliated variety of gypsum from the New Red marl of Seaton in Devonshire, is shown in No. 1384—a specimen presented by the late Sir W. C. Trevelyan.

Gypsum is sometimes known as *Plaster stone* in consequence of its use in the production of Plaster of Paris, and as *Potters' stone*, because so much is sent to the Potteries for use in the formation of moulds. Crystallized gypsum contains about 21 per cent. of combined water, and when properly calcined for plaster about three-fourths of this water is expelled. If the mineral be totally dehydrated it is spoilt, and the plaster is said to be "over burnt."† A Case on the western side of the Hall, near the window, illustrates rather fully the manufacture and uses of Plaster of Paris.

Cavities occasionally occur in the masses of Triassic alabaster, and on the walls of these cavities the gypsum often occurs in beautiful crystals. The crystallized gypsum is known as *Selenite*, a name said to refer to the pearly sheen seen on the cleavage-planes, thought to be suggestive of moonshine.† A large series of crystals of selenite will be found here, including some very fine examples from the Kimeridge clay of Headington, near Oxford. The crystals belong to the monoclinic system, and exhibit perfect

---

\* "The Gypsum Deposits of Nottinghamshire and Derbyshire," by A. T. Metcalfe. *Trans. Fed. Inst.*, vol. xii. (1896) p. 107; *Rep. Brit. Ass.* for 1893, p. 760; *Forty-second Ann. Rep. Nott. Nat. Soc.*, 1895, p. 19.

† Although selenite derives its name from *σεληνη* (*selene*) the moon, the mineral must not be confounded with the "moonstone" of the jeweller, which is adularian felspar. See specimens in Horse-shoe Case, Section T.



cleavage parallel to the clinopinacoid. Many of the crystals are of tabular habit, and the large lozenge-shaped face seen on several of the specimens is this plane of easy cleavage. Thin transparent cleavage-flakes, mostly of diamond shape, were formerly used to a limited extent in place of glass. The mineral may be cleaved also, though less perfectly, in two other directions.

Twin crystals are common in gypsum, as seen in Nos. 1393, 1394 ; and the twinning may give rise to arrow-headed and swallow-tailed crystals. The faces are often curved, as in No. 1395, whilst in some instances the crystals become quite lenticular in shape, as in No. 1396. The specimen No. 1399 is a group of lenticular crystals from the Oldhaven beds of Reculver Cliff, in N. Kent, remarkable for having a large proportion of sand mechanically associated with the gypsum—an occurrence which reminds the mineralogist of the so-called “Fontainebleau sandstone,” in which calcite mixed with much sand has crystallised in rhombohedra. (See specimens in Horse-shoe Case, Section I.)

Crystals of selenite, often known in brickyards as “congealed water,” are common in most clays and in many shales, which are simply indurated and laminated clays. The mineral may be formed in such situations by the action of sulphuric acid or of sulphate of iron, resulting in either case from the decomposition of iron pyrites, on calcareous matter, such as that of shells. In limestone a similar reaction may occur. Crystals of gypsum have been formed artificially by allowing a solution of ferrous sulphate, in contact with air, to react on chalk, the gypsum being here accompanied by the formation of ferric hydrate. Such an association, brought about naturally, is illustrated by a specimen from Brighton in the Horse-shoe Case.

Examples of selenite are exhibited not only from the Keuper marl and from the Kimeridge clay, as mentioned above, but also from the Woolwich and Reading clays, as in No. 1398, presented by Dr. G. Abbott. The late Professor P. M. Duncan, in calling attention to the occurrence of moulds in certain Eocene clays, indicating the former presence of selenite, explained the removal of the mineral by assuming that deoxidation had been effected by means of decomposing organic matter, whereby the sulphate had been reduced to sulphide of calcium, which is an extremely unstable substance.\* Professor Lacroix has remarked that if calcium sulphide be acted on by a solution of acid carbonate of iron, the products of the reaction may be pyrites and calcite.† Gypsum may be readily removed from one spot and carried to another by mere solution in water. According to Mr. G. K. Cameron, one part of gypsum is soluble in 372 parts of pure water at 26°C. It is well known that

---

\* “On the spaces formerly occupied by Selenite in the Lower Eocene Clays of the London Basin ; with Remarks on the Origin and Disappearance of the Mineral.” *Quart. Journ. Geol. Soc.*, vol. xxii. (1866), p. 12.

† “Le Gypse de Paris.” *Nouv. Archiv. Mus. d’Hist. Nat.*, 3 ser.. vol. ix. (1897) p., 201.

waters draining gypseous rocks, like those of the Trent, contain much sulphate of lime in solution; and such permanently hard waters, valued for brewing as at Burton, are said to be "selenitic."

The decomposition of gypsum gives rise in some cases to the elimination of *Native Sulphur*, as shown in a specimen in the Hall, where sulphur is seen in a mass of gypsum from Newark. Mr. R. P. Cafferata has remarked that in the course of twenty-four hours after quarrying the "Blue Rock" free sulphur appears in considerable quantity.\* The reduction is generally effected by organic matter, probably through the agency of sulphur bacteria.†

Gypsum is readily converted into calcite, even in the cold, by the action of a solution of certain carbonates. A crystal of gypsum which has undergone this change will be found in the interesting group of artificial pseudomorphs, prepared and presented many years ago by Dr. H. C. Sorby, F.R.S., and exhibited in Wall Case 35.

According to official statistics the amount of gypsum raised in England in 1902 was 224,669 tons. This amount was yielded by the following counties, the first-named being the largest producer, and the others in regular sequence yielding less and less: Nottingham, Stafford, Cumberland, Sussex, Derby, Yorks, Westmorland and Somerset. Whilst most of the gypsum comes from the Keuper marl, it has been pointed out by Mr. J. G. Goodchild that the gypsum of Edenside is referable to a lower horizon, being on or near the Magnesian Limestone.‡

Widely different in geological age, from the Permo-triassic gypsum, is the gypsum of Sussex, of which a sample is here shown (No. 1385). This mineral was discovered in the famous sub-Wealden boring at Mountfield, near Netherfield, not far from Battle, and is believed to be of Purbeck age. Much gypsum occurs in the Isle of Purbeck, and the mineral was formerly worked in the lower Purbeck beds of Durlston Bay.§

### *Anhydrite* (No. 1400.)

Whilst gypsum contains two molecules of water of crystallisation, the mineral called *Anhydrite* is a sulphate of calcium destitute of water, whence indeed its name. Unlike gypsum, anhydrite crystallises in the orthorhombic system, but crystals are rare, at least in this country. Anhydrite is harder and denser than gypsum, and admits of being polished like a piece of marble. It frequently presents a pale blue colour, as seen in No. 1400.

Anhydrite readily passes into gypsum, with an increment of volume of about 60 per cent., and conversely gypsum may become converted into anhydrite. It has been suggested that much of the gypsum in

\* Cited by Mr. Metcalfe, *op. cit.*

† Prof. Lacroix: "Minéralogie de la France," vol. ii (1897), p. 370.

‡ "Some Observations upon the Natural History of Gypsum," *Proc. Geol. Assoc.*, vol. x (1888), p. 425.

§ "The Geology of the Isle of Purbeck." By Aubrey Strahan, M.A. *Mem. Geol. Surv.*, 1898, p. 237.



this country may have been derived from the alteration of anhydrite. In Nottinghamshire anhydrite occurs in the heart of certain masses of gypsum, and this kernel seems to represent the original mineral. It was formerly supposed that the production of anhydrite required a moderately elevated temperature, but it is now known that the mineral may be deposited at normal temperature, especially from saline solutions. The researches of Professor van't Hoff have shown that "solutions containing calcium sulphate which have a tension lower than 17.2 m.m. at 25° deposit it as anhydrite. This is the case in the deposition from sea-water."\*

*Celestite* (Nos. 1401, 1402.)

Native sulphate of strontium, like sulphate of calcium, is a mineral not infrequently found in the New Red Sandstone. Its occurrence in the Bristol district has already been described (p. 113) and some fine examples are exhibited in Case VII., but a specimen is also placed here, in order to illustrate with some approach to fulness the mineral products of the Trias (No. 1401).

*Celestite*, or *celestine*, is frequently found in association with gypsum, as illustrated by No. 1402 and by specimens in Section G of the Horse-shoe Case. Even when not detected by the naked eye the presence of celestite in gypsum may sometimes be revealed by the microscope. Natural waters, especially in the New Red Sandstone, often contain an appreciable quantity of sulphate of strontium. Its occurrence in the water of the famous dropping well of Knaresborough† and in the Bristol waters has already been referred to (p. 114).

Celestite is found in many sedimentary strata, though by no means so common a mineral as barytes. A specimen in the Case illustrating Fossilisation is interesting as showing celestite finely crystallised in the chambers of an ammonite from the Lias of Adderley in Shropshire.

Collectors of minerals are familiar with the flints of Meudon, near Paris, containing crystals of celestite, of which a specimen will be found in the Horse-shoe Case, but the mineral is not known to occur in the chalk-flints of this country.

*Barytes* (Nos. 1403 to 1406).

Barium is an element of much wider diffusion than the kindred element strontium, occurring as it does in a large number of rocks, both sedimentary and eruptive, and in many natural waters.‡ Attention has been called in recent years to the occurrence of barium in many of the Triassic sandstones. Mr. A. Strahan, in describing the rock of Beeston Castle in Cheshire, which is Keuper sandstone,

---

\* *Journ. Chem. Soc.*, vol. lxxxii (1902), Part ii., p. 138: abstract of paper by van't Hoff and Weigert in *Sitzungsber. K. Akad. Wiss. Berlin*, 1901.

† *Proc. Yorkshire Geol. and Polyt. Soc.*, new ser., vol. xiii., p. 135.

‡ See Delkeskamp's paper cited on p. 169.

alluded to the veins of *Barytes* in the joints of the rock, and to the occurrence of the mineral in the rock itself, as well as in the breccias of the Peckforton Hills.\* Prof. Clowes found barium sulphate in the Bunter sandstone of the so-called "Hemlock Stone," near Nottingham, where it occurs as a cementing medium uniting the siliceous grains.† Prof. W. W. Watts has described the occurrence of barytes under similar conditions in the Lower Keuper sandstone of Peakstones Rock, near Alton, in Staffordshire.‡ So again, the occurrence of barytes in both Bunter and Keuper sandstone at Bidston, in Cheshire, has been recorded by Mr. C. C. Moore and Mr. J. Lomas.§ It should be noted too that Dr. H. T. Brown has found barium existing in the form of carbonate in some of the Triassic sandstones in Cheshire, whilst Professor Clowes has suggested that the reaction of this soluble compound with certain sulphates may have led to the formation of barytes in the rocks. Gypsum is not uncommon in the sandstones of Nottinghamshire.

In mineral waters barium frequently exists in the form of chloride. An exceptionally large proportion was found by Prof. E. T. Thorpe in the waters of Harrogate, the water of the Montpellier Strong Sulphur Well yielding an amount of barium equivalent to 9.5 grains of chloride per gallon.|| It is notable, too, that the proportion of barium in the Harrogate water seems to be increasing. Barium chloride also occurs, to the extent of more than 6 grains per gallon in the waters of Llangammarch Wells in Breconshire.

As far back as 1847 Dr. Richardson detected barium in the waters of Walker Colliery, near Newcastle, and a large mass of barytes was found in Felling Colliery.¶ Prof. Clowes has called attention to the large proportion of barium in the waters of certain collieries in Durham, which is the cause of a deposit forming in the pipes and water boxes connected with the mining pumps. In some cases the deposit contains as much as 90 per cent. of sulphate of barium, and it is an interesting fact that sulphate of strontium is also present in the deposit, in some cases to the extent of 8 per cent. Prof. Bedson found barium chloride in the colliery waters, and, as Prof Clowes remarks, this solution would give rise to a precipitate of barytes by reaction with ferrous sulphate, or with free sulphuric acid, which might readily result from the decomposition of pyrites. In Case VIII. will be found a nodule of clay ironstone enclosing barytes, from the Whitehaven coal-field (No. 1091), and it is known that barytes likewise occurs in the Coalbrook Dale ironstone.

\* "The Geology of the Neighbourhood of Chester." *Mem. Geol. Surv. Expl. Quart. Sheet* 80, S.W. 1882.

† "Barium Sulphate as a Cement in Sandstone." *Proc. Roy. Soc.*, vol. xlv. (1890), p. 363.

‡ Rep. Brit. Assoc. for 1894, p. 665. *Geol. Mag.*, [iv.] vol. i. (1894), p. 520.

§ *Proc. Liverpool Geol. Soc.*, vol. viii. (1900), p. 241.

|| *Journ. Chem. Soc.*, vol. xxxix. (1881), p. 510.

¶ "On Minerals and Salts found in Coal-pits." By R. Calvert Clapham and John Daglish. *Trans. N. Eng. Inst. Min. Eng.*, vol. xiii. (1864), p. 219.



In the Triassic sandstone of Elgin barytes has been found, and here Dr. W. Mackie regards it as a precipitate from an inland sheet of salt water.\* Commander A. Carpenter dredged off Colombo, in the Indian Ocean, in 675 fathoms of water, small nodules containing 75 per cent. of barium sulphate.†

It is worth noting that certain crystals of barytes from Teplitz, described by Dr. F. Becke, appear to have been formed by precipitation from the hot springs, where, though the crystals reach a length of five centimetres, the proportion of barium in the water is so small as to elude analytical determination.‡

The finest specimens of barytes yielded by the Neozoic strata of Britain are the large yellow crystals formerly found rather abundantly, though now rare, in the pits worked for fuller's earth in the Lower Greensand of Nutfield, near Redhill, in Surrey (Nos. 1403–1404). As far back as 1819 this occurrence was described by Thomas Webster, who speaks of masses of barytes found here weighing a hundredweight.§ The crystals, which though large are rarely terminated, were studied by Prof. Chapman, of University College, London, who described the mineral as *barytine*.|| Some excellent examples of the Nutfield barytes are here shown, and others will be found in the Horse-shoe Case. The crystals, rather like sugar-candy in colour, are associated with crystallised quartz, sometimes slightly amethystine in tint. Iron-pyrites also occurs with the barytes, and a little carbonate of copper has occasionally been found. The presence of barytes was not favourably viewed by those who worked the fuller's earth.

Very different from the Nutfield mineral is the barytes occasionally found in the septaria of the London clay, especially in the Isle of Sheppey. Here it occurs in slender opaque white crystals, arranged in radiating forms or in stellate groups, and rather effectively disposed on the yellow calcite which has crystallised in the contraction-cracks of the nodules, and was formerly called the "waxen vein." This occurrence of barytes was recognised by such early observers as Dr. Grew and Sir John Hill, who described the mineral under the name of *lepastrum*, and appear to have regarded it as gypsum. Some of the specimens here shown (Nos. 1405, 1406) are said to have come from Whitstable Bay; and according to Sowerby the barytes was also found under similar conditions at Southend, at Sydenham, and at Highgate.¶

From the difficulty of dissolving sulphate of barium, it might be supposed that the mineral would be extremely immobile, not easily removed from one place and deposited in another. According

\* *Rep. Brit. Assoc.*, Glasgow, 1900, p. 649.

† *Journ. Asiatic Soc. Bengal*, vol. lvi. (1887), p. 209. Quoted in "Report of the Challenger."

‡ *Tschermak's Min. Mit.*, vol. v. (1888), p. 82.

§ "On the Geognostical Situation of the Reygate Stone and of the Fuller's Earth at Nutfield." *Trans. Geol. Soc.*, vol. v. (1819), p. 326.

|| "Mineralogical Notes," *Phil. Mag.* [4], vol. iii. (1852), p. 144.

¶ "British Mineralogy," vol. iii., p. 199; vol. v., p. 39.

to Holleman, one part of the salt requires for solution 429,700 parts of water at 18.4° C.\* Referring to the waters of Bath, the Hon. R. J. Strutt observes that "Barium sulphate requires half a million times its weight of water to dissolve it; radium sulphate perhaps several hundred million times its own weight."†

Barytes not infrequently contains a small proportion of the sulphates of strontium and calcium. With celestite the barytes is clearly isomorphous, but such relationship can hardly be extended to the corresponding calcium salt, for though anhydrite crystallises like the others, in the orthorhombic system, it yet differs markedly in form and in cleavage.

*Copper-Ores, etc. (Nos. 1407 to 1408).*

Copper is rather widely distributed through many sedimentary rocks, but is rarely present in large proportion, except in rocks of the New Red Sandstone period. Dieulafait referred the origin of the copper to deposition from sea-water. In the waters of the Mediterranean, he found copper to the extent of 0.01 gramme per cubic metre; and he showed that the black mud left by evaporation of sea-water, whether in natural or in artificial basins, invariably contained this metal.

Perhaps the most important copper-bearing rock of sedimentary origin is the famous *Kupferschiefer* or *copper-shale*, of Germany, which though only a thin stratum containing but 2 or 3 per cent. of copper, has nevertheless been worked for at least seven centuries, and still yields a large output of copper. The black shale is rich in fossil fishes, like *Palæoniscus*, and it was suggested by Groddeck that the discharge of cupriferous springs into the basin in which the mud was in course of deposition must have destroyed the fish-life, whilst the decaying organic matter would lead to the formation of sulphides. According to Dieulafait the copper might be derived simply from sea-water, by evaporation in a closed basin; the gypsum which would be deposited in the lagoon might suffer reduction by decomposing organic bodies, with the formation of sulphides, which would precipitate the copper, in a sulphuretted form. It is notable, however, that the *marl-slate* of Durham, which is a Permian deposit at the base of the Magnesian Limestone, on precisely the same horizon as the German copper-shale and closely related to it palæontologically, appears to be quite destitute of copper.‡

The copper-bearing strata of this country are almost exclusively of Triassic age. Reference has already been made to the occurrence of copper-ores in the Dolomitic Conglomerate of the West of

\* *Zeit. Phys. Chem.*, vol. xii., p. 125.

† *Proc. Roy. Soc.*, vol. lxxiii. (1904), p. 195.

‡ See Prof. Lebour's remarks in *Trans. Inst. Mining Eng.*, vol. xxiv. (1904), p. 390.



England (p. 112), but the most noteworthy examples of cupriferous strata are to be found in Cheshire, where sandstones and conglomerates, formerly regarded as Keuper but now referred by some authorities to the Bunter, have been systematically worked for copper at Alderley Edge and at Mottram St. Andrews, near Macclesfield, the beds being there repeated by a fault. The bright colour of the copper carbonates in these rocks probably attracted attention at a very early period; and the rude stone hammers found by Prof. Boyd Dawkins, Dr. Sainter, Mr. Roeder, and others, point to workings even in prehistoric times.\*

At Mottram St. Andrews the copper was worked chiefly in a hard quartzose conglomerate, which contained an average of about 5 per cent. of copper-ore. At Alderley Edge, about a mile to the south-west, the ores were mostly found in three beds of sandstone, where the proportion of copper averaged about 1·4 per cent. of the workable parts of the stone.† The grains of quartz in the sandstone were invested by a coating of copper carbonate. The specimen here exhibited (No. 1407) is a quartzose conglomerate, with malachite and azurite. The sandstones are variously coloured by several mineral pigments—yellow and brown by iron oxides, blue and green by copper carbonates, and black by manganese oxide and earthy cobalt-ore.

Although these cupriferous sandstones are no longer worked, they were at one time the object of rather extensive mining operations, and the ore was profitably treated by a wet process. The coarsely ground sandstone was digested with dilute hydrochloric acid, whereby the copper was dissolved out, and from this solution of the chloride the metal was precipitated by scrap-iron. The “cement copper” contained about 80 per cent. of metallic copper. The cobalt, which occurred to a small extent in the sandstone in the form of *asbolan*, was recovered by adding milk of lime to the liquor after removal of the copper. The precipitate thus obtained carried the cobalt, with a little arsenic. It is notable that copper is also accompanied by cobalt in many other localities, as at Bieber in Hesse.

Some of the Cheshire sandstones contained also lead ore, chiefly in the form of *cerussite*, though they likewise yielded subordinately *galena*, *pyromorphite* and *vanadinite*. A sample of Alderley Edge sandstone, with lead-ore is here exhibited as No. 1408. Attempts to treat the plumbiferous sandstones were not commercially successful. These stratified lead-ores rather remind the miner of the sandstones which are extensively worked near Mechernich and Commern, in Rhenish Prussia, where the Bunter sandstone contains nodules, or *Knotten*, of *galena*, associated with *cerussite* and locally with a little copper carbonate.

---

\* “Prehistoric and subsequent Mining at Alderley Edge,” by Charles Roeder. *Trans. Lancashire and Cheshire Antiq. Soc.*, vol. xix. (1902).

† *Mem. Geol. Surv. Prof. Hull’s Memoir on Geology of Stockport*. Also Mr. Greenwell in *Proc. S. Wales Inst. Min. Eng.*, vol. iv. (1866), p. 44.

Sir H. E. Roscoe many years ago described a vanadate of lead and copper, which was found at Alderley Edge and at Mottram St. Andrews, to which he gave the name of *Mottramite*. It formed on the sandstone a thin incrustation, in some cases black and velvety, with crystalline structure, and in other cases compact and of purplish brown colour.\*

It may not be without interest to recall the fact that other vanadates are elsewhere present with Permian copper-ores; witness the occurrence of *volborthite*, a vanadate of copper, in the cupriferous sandstone of Perm in Russia.

### *Iron-ores (Nos. 1409 to 1419).*

Of the many *iron-ores* found in the Secondary strata of Britain the most famous is the ore of the Cleveland district in the North-east of Yorkshire (No. 1409). The Cleveland ore occurs in the Middle Lias, or Marlstone, where it forms several bands, the most important seam being nearly twenty feet in thickness. Though not everywhere uniform in character, the ore when freshly raised is typically a light bluish-green oolitic rock, containing about 30 to 32 per cent. of iron, chiefly in the form of carbonate.† The greenish colour is referred to the presence of glauconite, or some other silicate of iron, whilst the bluish tint may be due to a phosphate like vivianite. Phosphorus is always present, though in variable proportion, the average being about 1·5 per cent. As the ore is highly fossiliferous the origin of the phosphorus is readily traced. Indeed the two principal beds of ore are known, from their characteristic fossils, as the *Pecten Seam* and the *Avicula Seam*. Traces of various extraneous metals, like zinc, nickel, and cobalt, are commonly present in the Cleveland ore; and Mr. A. Dick, in the course of an analysis found in the insoluble residue, microscopic crystals of *Anatase*, associated with quartz.‡ Titanium oxide, in the form of anatase and of rutile, has been shown by several recent observers to be widely distributed in the sedimentary rocks of this country.§ The presence of zinc in the Cleveland ore offers no difficulty, inasmuch as the frequent association of

\* "On two new Vanadium Minerals." *Proc. Roy. Soc.*, vol. xxv. (1876), p. III. The other mineral referred to in the title of the paper is the vanadium-mica called *Roscoelite* (p. 109).

† For full description of the Cleveland ore, see *Mems. Geol. Surv.* "The Geology of North Cleveland," by George Barrow, 1885, p. 80. "The Jurassic Rocks of Britain, vol. i., Yorkshire," by C. Fox-Strangways, 1892, p. 433.

‡ "The Iron-ores of Great Britain," (*Mem. Geol. Surv.*), part i., p. 95.

§ See Mr. Scrivenor's paper on "Anatase in the Trias of the Midlands of England," in *Min. Mag.*, vol. xiii. (1903), p. 348, where references are given to the work of Dr. J. H. H. Teall, Mr. Maynard Hutchings, Mr. A. Dick, and Mr. H. H. Thomas. In a paper on the "Distribution of Titanic Oxide upon the Face of the Earth" (*Am. Journ. Sc.* [3], vol. xlii., 1891, p. 491), Prof. F. P. Dunnington records his examination of "black garden soil from Kensington," which yielded 0·21 per cent. of titanic oxide. The common occurrence of titanium in iron-ores explains the origin of the cyano-nitride of titanium, which is occasionally found in small copper-like cubes in the "bear" of blast furnaces.



zinc-blende with carbonate of iron is well known, and is very marked in the Lias.\* According to Professor Hartley the Cleveland ore, like many other ores of iron, contains gallium.

From the microscopic structure of the Cleveland iron-ore, Dr. Sorby showed, many years ago, that it had probably been originally an oolitic limestone, which became altered by the action of a solution of bicarbonate of iron, derived perhaps from the interstratified shales which contained oxide of iron and organic matter.† In some of the fossil shells associated with the ore, the carbonate of lime is partially replaced by ferrous carbonate.

The Cleveland ore is raised at the present time (1904) to the extent of about 5,600,000 tons per annum, an amount which represents rather more than two-fifths of the total output of iron ore in the United Kingdom. The iron-ores of the Middle Lias have been worked not only in Yorkshire, but also in Lincolnshire, Leicestershire, and Oxfordshire. The ore of Frodingham in N. W. Lincolnshire is referable, however, to the Lower Lias.‡

At Rosedale Abbey, in Yorkshire, there occurs an oolitic ironstone of nearly black colour, peculiar in being magnetic and polar. This magnetic iron-ore represented by No. 1410, occurs in the Dogger series, belonging to the Inferior Oolite. Crystals of magnetite, as Prof. Lacroix has pointed out, occur in some of the oolitic brown iron-ores of France. The formation of magnetite in the wet way possibly receives illustration from an observation of F. M. Stapff, who found that the rust on nails from ancient mines in Spain, believed to be 2,000 years old, consisted of a mixture of limonite and magnetite.§

Prof. Bauerman has called attention to the similarity of the Rosedale ore to the mineral worked on the Continent under the name of *Chamoisite*—a pisolitic magnetic ore of Jurassic age.||

A vast quantity of siliceous brown iron ore is raised annually from the Oolites of this country.¶ The *Northamptonshire ore* (No. 1411) largely developed in the Northampton sand, forming part of the Inferior Oolite, presents the aspect of a rusty brown granular mass, composed of iron hydroxide and quartz. At considerable depths, however, the unaltered ore is a bluish or greenish grey substance,

\* See for instance, "The Yorkshire Lias," by Ralph Tate and J. F. Blake, 1876, p. 163. Also Mr. C. Fox-Strangways' *Geol. Surv. Mem. on the Jurassic Rocks of Britain*, vol. i., p. 473.

† "Origin of the Cleveland Ironstone." *Proc. Geol. Polytech. Soc. West Riding*, vol. iii. (1856-7), p. 460. Also: *Quart. Journ. Geol. Soc.*, 1879.

‡ See paper by the late Rev. J. E. Cross in *Quart. Journ. Geol. Soc.*, vol. xxxi. (1875), p. 115. Also, *Mem. Geol. Surv.* "The Jurassic Rocks," vol. iii. By Horace B. Woodward, 1893., p. 300.

§ *Jahrb. f. Min.*, 1895, part i., p. 69.

|| "A Treatise on the Metallurgy of Iron, 6 ed., 1890, p. 87.

¶ It may be noted that the Jurassic brown ores of Luxemburg and Lorraine are known as *minette*—a diminutive of *mine*, or ore. Iron-ore is often called in this country "mine," and the diminutive would indicate a lean or poor ore. *Minette* is used also as the name of an igneous rock.

composed mainly of impure ferrous carbonate. The bluish colour is regarded by Professor Judd, as probably due to the diffusion of a small proportion of iron sulphide throughout the mass, whilst the greenish tint may be referable to the presence of ferrous phosphate rather than to a silicate.\*

The brown iron ore of Westbury, in Wiltshire (No. 1413), and that of Abbotsbury, in Dorsetshire, are referable to the *Corallian strata*. At a slightly higher horizon is the brown iron ore, which was found in the Dover boring. This ore forms a band 12 feet in thickness, described by Prof. Boyd Dawkins as composed of grains of hydrated oxide of iron in a base consisting partly of carbonate of lime and partly of carbonate of iron.† The ore of Seend, near Devizes, in Wiltshire, occurs in the *Lower Greensand*; indeed much of this Greensand consists of iron-shot sands, and the proportion of iron occasionally rises sufficiently high to constitute a siliceous iron-ore. Examples of all the Jurassic and Cretaceous iron-ores are shown in the Wall cases 47 and 49, and others will be found in the Petrographical Collection.

Ironstone was formerly worked on rather a large scale in the *Wealden beds*, principally in the Wadhurst clay, but also to a limited extent in the Ashdown sands. The ore (No. 1414) is a kind of clay ironstone, containing as much as 35 per cent. of metallic iron. It was this ore that formed the raw material of the iron industry which flourished for ages in the Weald of Sussex and Kent, and was not extinguished until the early years of the nineteenth century. Many of the "bell pits" from which the ore was raised still exist, though now generally filled with water. The ore was smelted with charcoal as a fuel—the charcoal being mainly derived from the oak forests on the Weald clay—and with the *Paludina (Viviparus)* limestone, or Sussex marble, as a flux. Cinder-heaps, or accumulations of old iron-slugs, still exist in the Weald.‡

In the Tertiary strata nodules of clay ironstone have occasionally been worked, as at Hengistbury Head in Dorsetshire, where the ore occurs in the Barton beds. The *bog* ores show the formation of iron-ore in progress at the present day, and may throw light upon the origin of some of the brown iron-ores of the sedimentary rocks. Mr. Hudleston has called attention to the fact that iron in rocks is rendered locomotive by means of carbonic acid, a soluble acid carbonate being formed, and is fixed by means of oxygen, the solution of bicarbonate on exposure to air depositing the hydroxide as a kind of bog ore.§

\* *Mem. Geol. Surv.* "Geology of Rutland," 1875. By John W. Judd. p. 110. "Jurassic Rocks," vol. iv. By Horace B. Woodward. p. 493.

† *Trans. Manch. Geol. Soc.*, vol. xxii. (1895), p. 501.

‡ *Mem. Geol. Surv.* "The Geology of the Weald." By William Topley 1875, p. 329.

§ "On the Geological History of Iron-ores." *Proc. Geol. Assoc.*, vol. xi., (1889), p. 104.



Organic agencies probably play a great part in the formation of deposits of bog iron-ore. The Rev. Dr. A. Irving has called attention to the importance of organic acids in the solution, the transport and the deposition of iron-ores.\*

It is known, too, that ferrous salts may be oxidised to the ferric state, without exposure to air, by the aid of ferro-bacteria. On the other hand, organic action may reduce the ferric hydroxide to the ferrous condition, and then, by means of carbonated water, a soluble bicarbonate may be formed. Kindler observed, as far back as 1835, that where pine trees were planted in sand-hills, the iron-shot sands became rapidly decolourised in the neighbourhood of the decaying roots.

Ferric hydrate has great agglutinating power, and masses of sand and gravel cemented by deposits of this substance are very common where chalybeate waters percolate through beds of loose material, forming what is known as "*pan*." By the filtration of meteoric water through ferruginous sands curious concretionary forms may be produced—tubular, globular, box-like, or quite irregular and capricious in shape (No. 1415). Some of the specimens from the Lower Greensand of Leighton Buzzard (Nos. 1416, 1417) look like rusty cannon balls, but they are often mere shells, and one of them broken open here displays the hollow interior. The nodules may enclose sand, or other substances, which rattle when the nodule is shaken. Such concretions were formerly called *Eagle stones*—a name applied also to other hollow stones, such as chalk flints, with loose matter in the interior. The most extraordinary virtues were formerly attributed to these nodules.† No. 1418 is an old specimen of an "eagle stone," or *Ætites*, mounted in silver, as an amulet, but this may not be British. That such ferruginous concretions may be of comparatively recent origin is shown by the discovery in Dordogne, some years ago, of what was described as a geode of hydrate of iron containing 200 silver coins of the sixteenth or seventeenth century.‡

Limonite, or brown iron ore, occurs not infrequently in stalactitic forms, which, when broken transversely, show a radial structure, the fibres being arranged in a direction normal to the axis of the stalactite. The surface is often lustrous, and this is specially notable in those varieties which contain manganese. Most bog iron-ore contains manganese in greater or less proportion. Examples of the rapid formation of stalactitic limonite are often to be observed in the deserted levels of old mines. Thus, Mr. Postlethwaite records a case in which the Woodend Mine, near Threlkeld, was re-opened after having been closed for thirteen years, and stalactitic and other

\* "Organic Matter as a Geological Agent." *Proc. Geol. Assoc.*, vol. xii. (1892), p. 227. See also on the Humus Acids, Prof. Julien, in *Proc. Am. Assoc. Adv. Sc.*, vol. xxviii. (1879), p. 311.

† "A Lapidary: or the History of Precious Stones." By Thomas Nicols, Cambridge, 1652, p. 148. "The Natural History, Ancient and Modern, of Precious Stones and Gems." By C. W. Kirg, M.A., 1865, p. 49.

‡ M. Marrot in *Bull. Soc. Geol. Fr.*, ser. ii., vol. iii. (1846), p. 527.

deposits of limonite filled up more than half the width of the level.\* The recent formation of stalactitic limonite is illustrated by No. 1419—a specimen from a shaft in the camp at Dolbury, near Churchill in Somersetshire.

It should be observed that certain kinds of brown iron-ore, bog-ore and ochre contain a larger proportion of water than exists in true limonite, and they should consequently be referred mineralogically to the species called *Limnrite* or *xanthosiderite*. The term *Stilpnosiderite* is sometimes applied to limonite which presents a pitchy black surface, generally connected, as remarked above, with the presence of manganese. The surface of bog iron-ore often appears scoriaceous, and may present a brilliant iridescence.

### *Glaucouite* (No. 1420).

Many sedimentary rocks, especially sandstones, are speckled with dark green grains of the mineral called *Glaucouite*. This is essentially a silicate of iron and potassium, but presents such a variability of composition as to suggest that it is a mixture rather than a true species. The specimen No. 1420, representing the green colouring matter of certain beds of Lower Greensand at Compton Bay in the Isle of Wight, was examined microscopically by Dr. Teall and analysed by Mr. Hort Player, who found that it yielded 9·6 per cent. of alumina.†

The grains of glaucouite are usually the internal casts of the chambers of foraminifera, or are otherwise connected with organic structures. The mineral may have been derived from the alteration of pyrites or of certain ferro-magnesian silicates. By meteoric influences it may become converted into ferric hydrate, and hence many sandstones which are green where unexposed become rusty at the outcrop.

It is noteworthy that the green sands and muds found by the "Challenger" in shallow water, along Continental shores, are characterised by the presence, more or less abundantly, of glaucouitic grains and casts, associated with green amorphous matter, probably, at least in part, of organic nature. Glaucouite is also present, though in smaller proportion, in the blue muds. It is most abundant near the "mud line" surrounding Continental shores, that is, at about the lower limit of the action of waves, tides and currents.‡

With regard to the origin of the glaucouite, it has been suggested that the mud which gained access to the interior of a shell or test might contain iron sulphide which became oxidised, and the sulphuric acid resulting from this alteration would form by acting on the clay aluminium sulphate with elimination of colloidal silica, which in a nascent state might combine with the oxide of iron in the mud. As

---

\* "Mineral Springs near Keswick," *Trans. Cumberland and West. Assoc.*, No. 11.

† *Mem. Geol. Surv.* "Geology of the Isle of Wight." 2nd ed., 1889, p. 255.

‡ "Challenger" Report, "Deep Sea Deposits." 1891, p. 378.



to the potash, it seems to have been derived from the sea-water itself, and probably owed its original source to the orthoclase and mica of the detrital matter.\*

*Pyrite (Nos. 1421 to 1424).*

Whilst certain rocks of subaqueous formation present a greenish colour which they owe to disseminated grains of glauconite, other sedimentary rocks—especially certain clays like the gault—are characterised by a dull bluish colour which has been referred to the presence of finely divided iron-pyrites.† In most eruptive rocks, *Pyrite* may be regarded as an original constituent, but in other rocks it occurs as a secondary product, formed generally by the alteration of various ferro-magnesian minerals.

In sedimentary strata the pyrites often owes its immediate origin to the reduction of a solution of ferrous sulphate, but this salt itself usually results from the oxidation of pyrites, so that the changes follow in a cycle. The reduction of the sulphate of iron by organic matter explains the common occurrence of pyrites in fossil shells, lignite and other organic structures. Instances of the recent formation of pyrites by decomposing organic matter are very familiar, one of the best being the case recorded by Pepys in which it resulted from the decayed bodies of mice which had fallen into a vessel containing a solution of ferrous sulphate.‡

Iron existing in solution as a carbonate, in water containing carbonic acid, may be converted into pyrites if sulphates and certain deoxidising agents be present. Thus, sulphate of lime in natural waters may be reduced by organic agencies, and the resulting sulphide, acting on the iron carbonate, may give rise to sulphide of iron. In other cases the sulphur may be supplied from organic sources. In the Percy Collection in the Victoria and Albert Museum there is a specimen (No. 3697) showing iron-pyrites in a log of wood from the yacht "Osborne," which had lain for a considerable time in a pond at Portsmouth that received the discharge of two drains.§

Pyrite is one of the commonest minerals in the Neozoic strata, occurring sometimes in cubic crystals, often in the form of nodules, and very frequently in disseminated grains (Nos. 1421, 1422). By early writers like Henckel, the German pyritologist, the crystallised

\* On Glauconite see also von Gümbel's paper, "Ueber die Natur und Bildungsweise des Glaukonits." *Sitzungsber. Akad. München*, vol. xvi. (1886). *Math.-Phys. Kl.*, p. 417.

† Ebelmen, for instance, referred the bluish tint of certain Cretaceous rocks to finely-disseminated pyrites (*Comptes rendus*, 22 Dec., 1851; *Bull. Soc. Geol. Fr.* [2], vol. ix., pp. 213, 221). It should, however, be added that Mr. Maw doubted the pigmental effect of pyrites. See his paper "On the disposition of Iron in Variegated Strata," *Quart. Journ. Geol. Soc.*, vol. xxiv. (1868), p. 351.

‡ "Notice respecting the Decomposition of Sulphate of Iron by Animal Matter." By W. H. Pepys. *Trans. Geol. Soc.*, vol. i. (1811), p. 399.

§ Catalogue of the Percy Collection (1892), p. 433.

pyrites was called "marcasite," or some variant of that word\* ; but the practice of modern mineralogists is to apply the term marcasite to the orthorhombic species of iron disulphide, and to restrict the name pyrite to the cubic species. The common term "iron-pyrites" is often loosely used, in a general sense, to include both modifications of the mineral—a practice not without convenience, inasmuch as it is sometimes difficult, in the absence of crystalline form, to determine to which species a given specimen belongs. It is true the colour of marcasite is paler than that of pyrites, but the colour is frequently deepened and disguised by tarnish. Density is said to offer a criterion. According to Prof. Julien, who has made a special study of pyrites, the specific gravity of normal marcasite is very near 4.8, whilst that of pure pyrite is approximately 5.01 ; but the density is subject to much variation, since the pyrite may be associated with marcasite in a state of intimate mechanical mixture, forming what has been called "marcasitic pyrite."† Some doubt, however, has been thrown upon this observation by Mr. H. N. Stokes.

Whilst some kinds of pyrites are very stable, others are extremely prone to decomposition. Two kinds of alteration are recognised. In one case, sometimes called the *hepatic* change, a slow oxidation occurs, whereby the pyrite becomes externally altered to limonite, with perfect preservation of form. Examples of this limonitisation have already been noticed in connection with such specimens as No. 428 (p. 61), and other pseudomorphs of brown iron oxide after pyrite are shown here (No. 1423). Such an alteration may be brought about either by the direct action of water containing oxygen or indirectly by conversion first into a carbonate and subsequently to hydroxide.

In the other kind of change, sometimes distinguished as the *saline*, the sulphide is oxidised to ferrous sulphate, known as a mineral under the name of *melanterite*, with elimination of free sulphuric acid. The *melanterite* itself may then suffer decomposition, forming basic ferric sulphates, like *copiapite* and *apatelite*,‡ with further production of sulphuric acid. It has been said that vitriolisation is more common with marcasite than with normal pyrite ; and where pyrite suffers such a change there is probably some admixture with marcasite. In some of the pyritised fruits of the London clay of Sheppey examined by Julien, the presence of distinct octahedra showed the existence of true pyrite, but it was probably accompanied by marcasite.§

The so-called 'marcasite' jewellery of the eighteenth century was invariably true pyrite, the brilliant polished surface of the mineral

\* "Pyritologia ; or a History of the Pyrites, the Principal Body in the Mineral Kingdom." Translated from the German. London: 1757. p. 14.

† "On the Variation of Decomposition of the Iron Pyrites, its Cause and its Relation to Density." By Alexis A. Julien. *Ann. N. Y. Acad., Sc.*, vol. iv. (1888).

‡ "Sur les produits de décomposition des pyrites, &c." Par M. A. Lacroix. *Bull. Soc. Fr. Min.*, vol. xx. (1897), p. 288.

§ "The microscopical structure of the Iron Pyrites." *Journ. N. York Micro. Soc.*, May 7, 1886.



being remarkably stable. A string of crystals of pyrite, believed to be from a British locality, is here shown (No. 1424). Such ornaments, being formerly regarded as possessing medicinal virtue, were known as "Health stones" (*Gesundheitssteine*) and it was held that as the wearer sickened, so the stone tarnished.

*Marcasite* (Nos. 1425, 1426).

Since Haidinger in 1845 applied the name *Marcasite* to the orthorhombic species of iron disulphide and restricted the term pyrite to its cubic isomer, as previously explained, the names have been generally used by mineralogists in this sense. The origin of the word marcasite, usually attributed to an Arab source, has been the subject of much learned discussion.\*

Some of the best known crystals of marcasite from the sedimentary strata of this country are the beautiful specimens from the Chalk Marl, between Dover and Folkestone.† They are usually groups of twin crystals of the spear-head type, supposed locally to be heads of Roman weapons.‡ Some excellent examples, attached to the matrix, are here exhibited (No. 1425). According to Prof. Hartley's spectroscopic studies, the marcasite of Dover contains thallium and nickel.§

The Chalk of the south-east of England likewise contains, especially in its lower zones, much marcasite in the form of nodules, sometimes spherical but often most capricious in shape, and displaying when broken a fibro-radiate structure (No. 1426). The exterior is often rusty, by limonitisation, but the freshly fractured surface is brilliantly metallic and of pale yellow colour. According to Mr. H. N. Stokes|| the colour of pure marcasite is tin white, and Prof. Julien makes the same remark, but tarnish or admixture with pyrite renders it brass-like. Exposure rapidly induces a yellow tarnish, which may pass into a brown colour. The nodules, often known locally as 'thunderbolts' and 'fairy-balls,' may enclose an organic nucleus; or a hollow may be left by disappearance of a fossil, and in this cavity pulverulent sulphur sometimes occurs—a substance set free by the disintegration of the molecule of iron disulphide. Some observers have recorded microscopic organic structure in the substance of the nodules. It has been pointed out by Mr. Stokes that a fibrous structure affords no clue to the species. "Fibrous pyrite appears to be much more common than fibrous marcasite."

Of all metallic sulphides, marcasite seems the most unstable, and its instability is generally responsible for the decomposition which

\* See, for example, Dr. Sadebeck's communication to the *Neues Jahrb. Min.* (1878), p. 289. "Ueber den Namen 'Markasit'."

† "Remarks on the Chalk Cliffs in the neighbourhood of Dover." By William Phillips. *Trans. Geol. Soc.*, vol. v. (1821), p. 36.

‡ Prof. Miers's "Mineralogy," p. 330.

§ "The wide Dissemination of some of the Rarer Elements, etc.," *Journ. Chem. Soc.*, vol. lxxi., part i. (1897), p. 533.

|| *Bull. U.S. Geol. Surv.*, No. 186, 1901.

pyritised structures frequently suffer. Several examples of fossils mineralised with iron disulphide will be found in the Case illustrating Fossilisation. The pyritic nodules, more or less altered, occurring in the Gault of Cambridgeshire are known locally as "rugg-stones."\*

Iron-pyrites, generally marcasite, was formerly used, like flint, for eliciting sparks by impact with steel; hence in old works there is sometimes confusion between pyrites and flint, both substances being called "fire stone" (*Feuerstein*).† The original word pyrites has similar reference to the use of the mineral in striking fire.

### *Quartz (Nos. 1427 to 1433).*

Crystals of *quartz* occur under various conditions in many of the Neozoic rocks. Some of the finest examples are found in the Dolomitic Conglomerate, especially in the interior of the potatostones of Bristol and the Mendip area. These have already been noticed (p. 113), but in addition to the specimens exhibited in Case VII. another is placed here in order to illustrate the minerals yielded by the Trias (No. 1427).

The *agates* of the Dolomitic Conglomerate on disintegration of the rock, may be preserved in the resulting detritus, and probably in this way the agates of the Litchfield drift have been derived. These agates are curiously altered, as seen in No. 1428, or still better in the large series, presented by Spencer G. Perceval, Esq., and exhibited in the Table-case of agates on the opposite side of the museum. In the Litchfield agates there are certain zones which have become dull and soft so that they adhere to the tongue, whilst some are reduced to a white opaque substance so soft as to yield to the finger nail.‡ Probably some of the layers contain both crystalline and colloidal silica, and the latter may be dissolved out by waters containing alkaline carbonates, or organic acids, leaving a residue which will be porous in consequence of the removal of the soluble part, and dead white by reflection of light, from the walls of the solution pores. The effect will be similar to that presented by the surface of certain weathered flints. Such de-opalised flint is sometimes known as *Passyite*.§

Quartz occurs in fairly large crystals under circumstances of rather exceptional character in the fuller's earth beds worked in the Lower Greensand at Nutfield in Surrey. The specimen No. 1429 shows the association of the colourless crystallised quartz with honey-yellow barytes. In some cases the Nutfield quartz presents a tint distinctly amethystine. It may be noted that the quartz is of subsequent formation to the barytes and occupies the space between the barytes-crystals.

\* *Mem. Geol. Surv.* "Geology of Cambridgeshire." By A. J. Jukes-Browne.

† See, for example, Sir John Pettus's *Fleta Minor*, 1683.

‡ "Notice of some Peculiarities observed in the Gravel of Litchfield." By A. Aikin, Esq. *Trans. Geol. Soc.*, vol. iv. (182 ), p. 426.

§ Lacroix's "Minéralogie de la France," t. iii. (1901), p. 132.



Some of the best examples of quartz from the Cretaceous beds are the crystals often found lining the interior of hollow flints from the Chalk, of which No. 1430 is a specimen. No. 1431 is an example of *chalcedony*, or microcrystalline silica, forming a mammillary coating on the walls of a cavity in a flint, whilst in No. 1432 the chalcedony hangs from the upper part of the hollow in small pendant stalactites. The specimen No. 1433 illustrates the curious conoidal fracture of flint—a character apparently connected with the uniformity of grain and mechanical isotropism of the flint. No attempt is here made to represent the varied forms and characteristics of Flint, as a large series of specimens will be found in the Petrographical collection, whilst others are seen in Section P of the Horse-shoe Case.

### *Allophane* (Nos. 1434 to 1436).

In 1856 the occurrence of *Allophane* was noticed at the chalk pits at Charlton, in Kent, by some of the students of the Royal School of Mines. Its mode of occurrence was described by Prof. Morris,\* and the mineral was analysed by Mr. A. Dick and by Mr. Northcote, who was attached at that time to the Royal College of Chemistry. The allophane, known to the quarrymen as “petrified water,” occurred as a white, yellow or brown amorphous substance, in nodules or irregular layers, often lining fissures and funnel-shaped cavities in the chalk, just at the junction of the Thanet sands (Nos. 1434, 1435). Mr. Northcote regarded it as a silicate of alumina with a variable amount of neutral hydrate.† It seems to be a product of the decomposition of certain aluminous silicates.

Allophane was discovered by the late Dr. Charles Berrill in the Northampton sand worked for ironstone, and the substance was analysed by Mr. Douglas Herman.‡ A specimen is shown in the Horse-shoe Case.

Related more or less nearly to allophane is the mineral substance known as *Scarbroite*—a hydrated silicate of aluminium, with a small proportion of silica, falling in some cases below 8 per cent. The mineral was discovered near Scarborough, by the Rev. W. Vernon Harcourt, and has been described by Mr. Fox Strangways as occurring in small veins in the Grey Limestone and in the Estuarine series above.§ A specimen of scarbroite is exhibited as No. 1436.

\* “On the Occurrence of Allophane at Charlton, Kent.” *Quart. Journ. Geol. Soc.*, vol. xiii. (1856), p. 13. See also *Mem. Geol. Surv.* “The Geology of London.” By W. Whitaker, B.A., F.R.S., vol. i. (1889), p. 527. Mr. Whitaker gives a list of the few minerals which occur in the London district.

† “On the Constitution of Allophane.” *Phil. Mag.* (4), vol. xiii. (1857), p. 338.

‡ *Quart. Journ. Geol. Soc.*, vol. xxvii. (1871), p. 234. See also Mr. Sharp’s paper: “The Oolites of Northamptonshire.” *Ibid.*, vol. xxvi. (1870), p. 367.

§ *Mem. Geol. Surv.* “The Jurassic Rocks of Britain,” vol. i., Yorkshire, 1892, p. 475.

*Aluminite or Websterite (Nos. 1437 to 1439).*

In the early years of the last century pieces of this substance were picked up by Mr. Thomas Webster, on the beach between Brighton and Beachy Head.\* It was described as a white substance resembling tobacco-pipe clay, and was at first regarded as pure alumina, but was shown by Wollaston and Smithson to be a hydrous sub-sulphate of alumina.† This mineral, called *Websterite* by most geologists, but known also as *Aluminite*—a name which, according to the law of priority, it ought to enjoy—occurs typically in the form of reniform masses, with a micro-crystalline structure, found at the junction of the Tertiary beds with the Chalk, especially at Newhaven (Nos. 1437, 1438). Its origin is not difficult to understand. Free sulphuric acid is readily formed by the oxidation of pyritic minerals, and this acid might decompose the silicate of alumina in the clays of the Lower London Tertiary series, or in other clays upon the chalk, with production of an aluminium sulphate.

Many years ago Mr. Spencer G. Perceval called attention to some deposits of websterite exposed in excavations at several localities in Brighton, where they occurred a few feet below the surface, in association with limonite and selenite, as seen in some of these specimens.‡ A very large mass of this Brighton websterite will be found in the Hall of the Museum, under a Table-case on the eastern side, near the window, and a small specimen is placed in this Case (No. 1439.) The brown ochreous material represents the iron of the pyrites, whilst the selenite has been formed from the chalk, or from shells, by the action of sulphuric acid, set free on decomposition of the pyrites. Some of this websterite is coated with a black deposit, in which the late Dr. Flight found manganese and cobalt.

In describing the websterite discovered during the drainage works in the Montpelier district in the N.W. of Brighton, the late Mr. James Howell remarked that the mineral was found rather plentifully in chalk districts wherever pyrites was associated with clay.§

Some confusion has been introduced into nomenclature by the fact that the name websterite has also been given to a certain pyroxenitic rock. There is consequently the more reason why the name should be detached from the mineral, and the mineral distinguished as aluminite.

*Calcite (Nos. 1440 to 1444).*

Crystals of calcite may occur in the fissures of any calcareous rock, and are common in many Neozoic limestones. Such crystals, however, are generally not equal in size or in beauty of form to those from the older rocks or from mineral veins.

A few examples of calcite from limestones and other deposits of Secondary age are here exhibited. In the Triassic beds, calcareous

---

\* *Ann. Phil.* vol. i. (1813), p. 467.

† *Ibid.*, vol. ii. (1813), p. 238.

‡ *Geol. Mag.*, vol. viii. (1871), p. 121.

§ *Rep. Erit. Assoc.*, Brighton, 1872, pp. 108, 106.



spar occasionally occurs, and is usually coloured red with oxide of iron, as in No. 1440. Crystals lining the potato stones from the Dolomitic Conglomerate are similarly tinted, as shown in Case VII. The rock from near Wells, described by Buckland and Conybeare under the name of "wonder stone," was a breccia containing yellow transparent crystals of calcite in a dark red dolomitic matrix.\*

In the interior of fossil shells calcite is not infrequent. No. 1443 shows the mineral crystallised in the cavity of a *Terebratula* from the Great Oolite. No. 1441 represents the columnar calcite, known from its colour and structure as "sugar candy," occurring in fissures in the Portland quarries. Fibrous calcite from the Purbeck beds is often termed by quarrymen "beef"—a name suggestive of its resemblance to the fibres of muscular tissue. The specimen No. 1442, presented by Clement Reid, Esq., F.R.S., is a good example of crystallised calcite from the Upper Chalk of Corfe Castle.

Calcareous deposits, of stalagmitic and stalactitic character, are common in the cavities in calcareous rocks of all ages, and are in course of formation at the present time whenever waters containing carbonate of calcium percolate through the rocks under conditions which favour precipitation. Stalactites of recent formation may often be seen hanging from the soffits of railway arches, for even when the arch is built of brick the mortar furnishes a supply of lime. A series of stalactites and stalagmites will be found in the Collection of rock specimens at the southern end of the Museum.

#### *Jet and Amber (Nos. 1445 and 1446).*

A few substances generally regarded as minerals but evidently formed, directly or indirectly, from organic sources, are here grouped together, at the end of the series of specimens representing the mineral resources of Southern Britain. Among these so-called "organic minerals" *Jet* occupies a conspicuous place. It appears, however, from the official statistics that no jet has been obtained in this country since 1897.

The jet, formerly worked rather extensively at Whitby in Yorkshire, occurs there in the Upper Lias shales. It is usually regarded as a compact variety of lignite, and, indeed, some varieties show the microscopic structure of coniferous wood, but the tissues seem to be impregnated with bituminous matter, and in many cases the vegetable structure is completely obliterated. A jet-like substance occasionally forms the mineralising material of certain fossils, especially the scales of fishes; drops of liquid bitumen occur in the chambers of ammonites and in the interior of nodules in the jet rock; and inflammable gases sometimes accumulate in the old workings. It seems not unlikely that masses of vegetable matter like tree trunks may have sunk, water-logged, in the black mud of the Liassic sea—the mud itself partly derived, perhaps, from the disintegration of the

\* *Mem. Geol. Surv.* "Geology of East Somerset." By H. B. Woodward, F.R.S., 1876, p. 63.

Coal Measure shales, and the material thus buried, without access of air, would undergo conversion into a lignitic substance, whilst a kind of natural destructive distillation yielded bituminous matter which saturated the product.\* Mr. A. C. Seward finds that much of the Whitby jet was formed from drifted wood of Araucarian type.†

Jet was formerly obtained from nodules picked up on the beach, but when this supply became exhausted the cliffs were attacked, and the jet-rock ultimately worked by simple burrowing.

On the Norfolk coast, in the neighbourhood of Cromer, jet is occasionally thrown up on the beach, especially after east winds. This appears to be different from Yorkshire jet, and is regarded by Mr. Clement Reid as probably derived from Lower Tertiary beds, buried under the North Sea. To a similar source must probably be referred the *Amber* which is sometimes found on the coast of East Anglia. A few pieces of such amber are here shown (No. 1446), and some finer specimens will be found in Section C of the Horse-shoe Case, including a piece of pale clouded amber, dredged off Yarmouth, weighing as much as 37 ozs., and another piece, differing markedly from the former by its deep orange colour, found on the coast of Cromer, and weighing 28½ ozs.‡ The specimens in the tray No. 1446 were presented by C. Reid, Esq.

*Copaline, etc. (Nos. 1447, 1448).*

Various mineral resins, more or less allied to amber, yet rarely if ever suitable for ornamental purposes, occur occasionally in the stratified rocks of Britain. No. 1447 is an example of such a substance from the Upper Greensand of Black Gang Chine, in the Isle of Wight; whilst No. 1448 is a specimen of the well known fossil resin from the London Clay of Highgate, often called *Copaline*, or *Highgate Resin*. This was first detected nearly a century ago by Mr. B. G. Snow, a local surgeon, whilst the tunnel was being driven through Highgate Hill. Sowerby, writing in 1817, speaks of a great quantity having been found, "perhaps a peck or two,"§ but most of it disappeared by disintegration. Samples were sent by Sowerby to Dr. Thomas Thomson, who was led from his analysis to regard it as approaching nearest in character to copal and amber.|| Its chemical properties, however, according to the doctor, threw no light on its

\*On the occurrence of jet at Whitby see *Mem. Geol. Surv.* "The Geology of the Country between Whitby and Scarborough." By C. Fox-Strangways and G. Barrow, 1882. "The Geology of North Cleveland." By G. Barrow, 1888; and "The Jurassic Rocks," vol. i., Yorkshire. By C. Fox-Strangways, p. 455. Also, "The Geology of Yorkshire." By R. Tate and J. F. Blake.

†*Rep. Brit. Assoc.* for 1903, p. 841.

‡On East Anglian amber and jet, see *Mem. Geol. Surv.* "The Geology of the Country around Cromer." By Clement Reid, F.R.S., 1882, p. 133. Also, "On Norfolk Amber," by same author, *Trans. Norfolk Nat. Soc.*, vol. iii. (1884), p. 601. *Ibid.* vol. iv. (1886), p. 247.

§"British Mineralogy," vol. v., p. 230.

|| "Description of a Resinous Substance Lately Dug Out of the Earth at Highgate." *Ann. Phil.*, vol. ii. (1813), p. 9.



origin, and could not, to use his words, "facilitate our enquiries into the revolutions which the southern part of this kingdom has undergone, and the various animal and vegetable remains so thickly scattered in its bowels." As a matter of fact, the substance seems to be merely a resinous exudation from certain coniferous trees which flourished on the land drained by the great London Clay River. It was found not only in small lumps in the clay, but attached to fossil wood, bored by teredo, and in some cases on septaria, whilst it was frequently associated with pyrites.

According to Prof. F. W. Johnston, who analysed a large series of carbonaceous minerals, the Highgate substance is nearly, if not absolutely, identical in constitution with the *gum animé* of Cayenne.\* It was this, or a similar body, that was described by Dr. Wetherell, in 1838, as having been found in the railway cutting at Chalk Farm, where it was associated with much pyrites, and also in a septarium at Highgate Archway, close to certain vegetable remains. The relation of the pyrites to the resin may be sufficiently explained by the reducing action of the carbonaceous matter.

It seems likely that it was a resin of like character that is referred to by Dr. John Woodward, when he speaks of "amber, brown and fossil, found at least thirty feet deep in the pit where they dig clay to make tiles at Richmond, Surrey"; and he adds: "The workmen call it rosin." True amber is said to have been found in the gravel pits at Kensington.

Certain mineral hydrocarbons have already been referred to as occurring among the older rocks (p. 178), and other bituminous substances are occasionally found among the Neozoic strata. These may assume the solid form of *asphalt*, or the liquid state of *petroleum*, or even the gaseous condition. *Natural gas* is now obtained industrially at Heathfield, in Sussex, where it appears to rise from sands and sandstones of the Lower Wealden beds and from certain Purbeck strata. The occurrence of the gas at Heathfield was described by Mr. Charles Dawson,† soon after its discovery, and has recently been the subject of some geological observations by Mr. H. B. Woodward.‡

\* "On the Composition of Certain Mineral Substances of Organic Origin: vi. Highgate Resin, or Fossil Copal." *Phil. Mag.*, vol. xiv. (1839), p. 87.

† "On the Discovery of Natural Gas in East Sussex." *Quart. Journ. Geol. Soc.*, vol. liv. (1898), p. 564.

‡ "Notes on the Occurrence of Natural Gas at Heathfield, Sussex." *Mem. Geol. Surv.* Summary of Progress for 1902, p. 135.

## DIVISION 2

## MINERALS OF SCOTLAND.

## MINERALS OF THE LEADHILLS DISTRICT.

(Nos. 1449 to 1504.)

A collection fairly representative of the minerals of Scotland is exhibited, partly in Case XI and partly in Case XII. According to a List communicated to the British Association in 1901, by Mr. J. G. Goodchild, there are about 180 species of minerals known to occur in Scotland.\* The collection here exhibited, though containing some very fine specimens, cannot be regarded as large when compared with the extensive display of local minerals in the Royal Scottish Museum in Edinburgh, which includes the famous collection made by the late Dr. Heddle. For further information respecting the minerals of Northern Britain the visitor may be referred to the comprehensive work on "The Mineralogy of Scotland," by this authority, published posthumously, under the editorship of Mr. Goodchild.†

The first group of Scottish minerals exhibited in the Case now under notice illustrates the well-known ore-deposits of the mining country around Leadhills, in the south of Lanarkshire, and the neighbouring district of Wanlockhead, on the borders of Dumfriesshire. Here, in a wild and elevated tract of the Southern Uplands, veins of lead ore, coursing through rocks of Lower Silurian (Caradoc) age, have been worked from a very early period.‡ Documentary evidence traces the history back to the thirteenth century, but according to some authorities mining was probably carried on here during the period of the Roman occupation, or even in prehistoric times.§

It is not, however, simply the lead-ore which has rendered this district famous in the annals of British mining. *Gold* was formerly found in considerable quantity, and even now grains of the precious metal may occasionally be obtained by washing the alluvium of the burns. The gold of Crawford Moor is said to have been discovered in the reign of James IV., and the celebrated "bonnet pieces" were minted of this metal. At various periods in the course of the sixteenth century, considerable activity prevailed, and at one time

\* "A List of the Minerals known to occur in Scotland." *Rep. Brit. Ass.*, Glasgow, 1901, p. 649.

† "The Mineralogy of Scotland." By the late M. Forster Heddle, M.D. Edited by J. G. Goodchild. 2 vols. Edinburgh, 1901.

‡ The geological structure of the district is described in *Mem. Geol. Surv.* "The Silurian Rocks of Britain, vol. i., Scotland." By B. N. Peach, F.R.S., and John Horne, F.R.S.E. With Petrological Chapters and notes by J. J. H. Teall, M.A., F.R.S., 1899.

§ "The Silurian Districts of Leadhills and Wanlockhead, and their Early and Recent Mining History." By John R. S. Hunter, D.Sc., LL.D. *Trans. Geol. Soc. Glasgow*, vol. vii. (1885), p. 373.



Sir Bevis Bulmer worked to such good purpose that he was able to present to Queen Elizabeth a porringer made of gold from this locality. Nuggets weighing several ounces each, in one case reaching as much as 30 ozs., have been recorded.\*

It is probable that the gold of this district has been derived from the disintegration of pyritic quartz-veins. Heddle refers to a brown iron-ochre from the Scar Burn, on the upper waters of Wanlock, which yielded more than five dwts. of gold to the ton.† This may well have been a gozzany ore, resulting from the alteration of auriferous pyrites.

At the present time, the Museum is not in possession of any examples of the gold of Crawford Moor. The few specimens of Scottish gold exhibited in Wall-case 14 were obtained, in 1869, from Kildonan Burn, in Sutherlandshire.‡

*Silver* is yielded to a moderate extent by the lead-ore of the Southern Uplands. In 1902 the mines of Wanlockhead produced 899 tons of lead-ore yielding 4,944 ounces of silver; whilst those of Leadhills turned out 730 tons of ore, with 2,555 ozs. of silver.§ Two excellent examples of crystallised *galena* are here exhibited as No. 1449.

In the shallow workings of the lodes in the Leadhills district, a great variety of oxidised products was formerly obtained, including several species not found elsewhere in Britain, or found only in the lead-veins of Caldbeck Fells in Cumberland (p. 152). The rarer minerals were obtained almost exclusively from the Susanna Mine at Leadhills. Excellent representatives of all these species, such as are to be found only in collections made many years ago, are exhibited in the Case now under review.

No. 1450, according to an old label, is a specimen of *Minium*, or native red lead, from Leadhills. This rare mineral, appearing here as a pulverulent incrustation, of brilliant scarlet colour, is evidently an alteration-product of other plumbiferous species. The authenticity of specimens of minium in old collections is not always free from doubt, but there seems no reason to regard this specimen as other than genuine.

\* See "The Discoverie and Historie of the Gold Mynes in Scotland." By Stephen Atkinson. Printed by the Banantyne Club, Edinburgh, 1825. Also, "Early Records relating to mining in Scotland. Collected by R. W. Cochrane-Patrick of Woodside." Edinburgh, 1878. Reference may be made to several papers on Scottish gold by Dr. Lauder Lindsay, such as "The Gold and Gold-Fields of Scotland." *Trans. Edin. Geol. Soc.*, vol. i. (1870). p. 105. See too "Historical Notes on the Occurrence of Gold in the South of Scotland." By Patrick Dudgeon, *Min. Mag.*, vol. i. (1877). p. 21. Also: "The Occurrence of Gold in Great Britain and Ireland." By J. Malcolm MacLaren. *Trans. Inst. Min. Eng.*, vol. xxv. (1904). p. 435.

† "The Mineralogy of Scotland," vol. i., p. 7.

‡ On the occurrence and probable source of the Sutherlandshire gold, see Mr. E. Greenly's "Notes on the Sutherland Gold-Field." *Trans. Edin. Geol. Soc.*, vol. vii. (1899), p. 100. This paper contains a bibliography of the subject.

§ Home Office Report for 1902, p. 244.

A good suite of specimens, numbered 1451 to 1456, serves to illustrate the occurrence of *Cerussite*, or lead carbonate, in the veinstones of Leadhills. Cavities within the zone of oxidation not infrequently contained this mineral, crystallised in well-defined forms, and associated with other oxidised lead-ores in such relationship as to suggest a rather late origin for the cerussite. The crystals in No. 1455 present a blackened appearance, due perhaps to the action of sulphuretted hydrogen. Mr. Goodchild has suggested that the lead-grey colour of some of the cerussite may be due to the presence of lead dioxide. The Leadhills district was at one time rather remarkable for the beauty and variety of its crystallised cerussites.\*

*Pyromorphite*, or chloro-phosphate of lead, finds illustration in the specimens Nos. 1457 to 1460. Whilst some of these examples of the mineral are of green colour, others are yellow, orange, and even red. The bright orange-coloured variety, which was raised in the Susanna Mine, has been sometimes regarded as a chromo-phosphate; but Dr. Norman Collie remarks that no chromium is revealed by the analyses.†

Probably certain compounds of vanadium may be responsible for the tints in some of the coloured phosphates. Isomorphous with pyromorphite, is the mineral called *Vanadinite*, a vanadate of lead, for which the mines of Wanlockhead have been in their day rather famous. This rare mineral, as seen in Nos. 1461 to 1464, crystallises in small hexagonal prisms, but is usually found in globular aggregates, of pale brown colour. Dr. Heddle records a crystal formed partly of vanadinite and partly of pyromorphite—a striking proof of the isomorphism of the two species. According to Mr. Goodchild “the vanadium in the Leadhills Mines may possibly have originated through the decomposition of the ferro-magnesian silicates present in the Arenig lavas there, as small traces of vanadium can usually be detected in the fresh minerals in question.”‡ The wide distribution of vanadium is attested by the spectroscope.

Some excellent examples of *Anglesite*, or lead sulphate, are exhibited here as Nos. 1465 to 1472. These show the characteristic dagger-shaped crystals, of exceptional size and perfection. The association of the mineral with decomposed galena in No. 1470, at once betrays its origin. Far more interesting, however, than the simple sulphate of lead are the crystallised basic sulphates and sulphato-carbonates, for which the Leadhills district is renowned.

*Lanarkite*, considered to be the rarest of all the minerals of Leadhills, is a basic sulphate of lead, which was originally described as a sulphato-carbonate. It occurs in small monoclinic prisms, and in diverging aggregates of long slender crystals; some of the crystals

\* See Mr. J. G. Goodchild's "Contributions to Scottish Mineralogy." *Proc. Roy. Soc. Edin.*, vol. xxiv., part iii. (1902), p. 321.

† "On some Leadhills Minerals." *Journ. Chem. Soc.*, vol. lv. (1889), p. 91.

‡ "Contributions to Scottish Mineralogy." *Op. cit.*, p. 338.



presenting a pale greenish tint. The characters of the mineral and the nature of its associates are well seen in the specimens, Nos. 1473 to 1478. According to Heddle this species was found only at the Susanna Mine. Among the accompanying minerals will be noted a group of other secondary species, such as caledonite, leadhillite, linarite and cerussite, with galena, the parent-mineral of the whole family.

The beautiful crystals of *Linarite* will arrest the attention of the visitor by their fine azure-blue colour—a colour which has occasionally led to the mineral being mistaken for chessylite, or blue carbonate of copper. Whilst lanarkite is a basic sulphate of lead linarite is a basic sulphate of lead and copper. It has already been referred to in connection with its occurrence at Roughten Gill (p. 157), but the Leadhills specimens here exhibited (as Nos. 1479 and 1480) are even finer than those in Case IX. from the Cumberland locality.

*Caledonite*, one of the rarest minerals of Leadhills, is another basic sulphate of lead and copper, though originally described as a cupreous sulphato-carbonate of lead. It occurs in small greenish-blue crystals of prismatic habit, as shown in the specimens Nos. 1481 and 1482, where it occurs in association with leadhillite and lanarkite. Dr. Collie suggested that caledonite might be regarded as a hydrated form of lanarkite, in which lead was partly replaced by copper.

A fine series of specimens, comprised under Nos. 1483 to 1492, represents the characteristic species named *Leadhillite*. This is a basic sulphato-carbonate of lead, occurring in crystals of tabular habit, belonging to the monoclinic system, and presenting a marked pearly lustre on the cleavage-planes. According to Dr. Heddle, it occurred in all the mineral veins of the Leadhills and Wanlockhead Mines.

Closely related to the true Leadhillite, of which it is probably but a variety, is the mineral named *Susannite*, after its occurrence in the Susanna Mine at Leadhills. Optically it presents uniaxial characters; but Prof. Groth suggests that this may be due to repeated lamellar growth.\* It has been pointed out by Mr. L. J. Spencer that three distinct kinds of leadhillite may be recognised: first, the ordinary monosymmetric leadhillite; secondly, the susannite which has been described as rhombohedral; and thirdly, an orthorhombic type, which he has found in the old lead slags of the Mendip Hills (p. 108).† Although similar to each other in general external characters, each kind has probably a definite chemical composition, and discrepancies in the analyses may be due to intimate admixture of these varieties. Dr. Collie has called attention to the apparent inconstancy in the ratio of the sulphate and carbonate in this species. Nos. 1489 to 1492 are specimens of susannite, exhibiting its typical characteristics.

\* "Tabellarische Uebersicht der Mineralien." 4 ed. 1898., p. 71.

† "Leadhillite in ancient lead-slugs of the Mendip Hills." *Rep. Brit. Ass.*, Bristol, 1898, p. 875; *Geol. Mag.*, new ser., Dec. 4, vol. vi. (1899), p. 71.

Ores of *zinc* occur, to a limited extent, with those of lead in the veins of the Leadhills district. *Blende*, as usual, is associated with the galena; but though fine crystals are occasionally found they are not common, and there are at present no examples in the collection. The silicate of zinc, previously noticed under the name of *Hemimorphite*, occurs at Wanlockhead, sometimes in acicular crystals, but more often in massive or botryoidal forms, not infrequently invested with variously coloured pyromorphite. As an example of its comparatively recent formation, Dr. Heddle records its occurrence as a chalky deposit on some old timber at the Bay Mine, Wanlockhead.\* Calamine, or carbonate of zinc, is not included as a Scottish mineral in Mr. Goodchild's List. In the year 1902 there were raised at Wanlockhead 110 tons of zinc-ore.

Associated with the lead and zinc ores of the Leadhills tract, *copper-pyrites* and its various alteration products occur in subordinate quantity. No. 1493 is a specimen of *Malachite*, showing by its association with galena and with cerussite that both the lead and the copper ore have suffered conversion into carbonates. In the rare species *Aurichalcite*, represented by Nos. 1494 and 1495, copper and zinc occur together as a basic carbonate, though free carbonate of zinc, as previously noted, is not recorded from these deposits. The aurichalcite occurs in delicate acicular crystals, forming divergent groups, of a pale green or sky-blue colour, associated with the rare species, *lanarkite*. With these Scottish specimens of aurichalcite may be compared the examples of the same mineral from Cumberland in Case IX. (p. 158).

Several specimens are exhibited in illustration of the various sparry minerals which occur in the veinstones of the Leadhills Mines. No. 1496 is a geode of *barytes*, and No. 1497 a specimen of *calcite* in opaque white scalenohedra, on which are seated small saddle-shaped crystals of pale brown *dolomite*. Most of the Leadhills calcite contains, according to Dr. Collie, more or less carbonate of lead, and when the proportion becomes notable the mineral is usually called *Plumbocalcite*—a name given to it in 1829 by Prof. J. W. Johnston. This plumbiferous calcite occurs in dull white rhombohedra, rather denser than pure calcite. It is regarded as an isomorphous mixture of the carbonates of lead and calcium in variable proportion, and is theoretically interesting since it suggests the existence of a rhombohedral carbonate of lead. This compound is therefore probably dimorphous, forming an orthorhombic species—the ordinary cerussite, which corresponds to aragonite, and a rhombohedral species not yet known in a free state. Just as the two rhombohedral species occur together in plumbocalcite, so the two orthorhombic species are associated in the mineral called *Tarnowitzite*.† Dr. Norman Collie has published analyses of *Plumbo-aragonite* from Leadhills, proving that the

---

\*"The Mineralogy of Scotland, vol. ii., p. 73.

† See Prof. Miers' "Mineralogy," p. 227.



aragonite of this locality may contain a small proportion of lead carbonate, though his specimen was not so highly plumbiferous as the typical tarnowitzite of Silesia.\*

Some excellent examples of *Aragonite* from Leadhills are exhibited here as Nos. 1501 to 1503. In one specimen (1501) the mineral occurs in white slender crystals on calcite, whilst in the other specimens the crystals are of a delicate sea-green tint, acicular in habit and disposed in divergent groups. Dr. Heddle examined some green crystals from Leadhills, which had been regarded as strontianite, but found that they contained only 1·7 per cent. of carbonate of strontia, and were practically aragonite.†

With regard to the origin of the minerals at Leadhills, it is probable, as Mr. Goodchild suggests, that although the metalliferous veins may have had a very complicated history, the introduction of much of the mineral matter may have been due to the uprise of thermal solutions in fault-fissures during the later phases of volcanic activity in Tertiary times.

#### MINERALS FROM STRONTIAN.

(Nos. 1505 to 1516.)

Although the minerals of Strontian ought strictly to be placed with those of the Highlands in Case XII., it has been deemed desirable to sacrifice the topographical arrangement in order to utilise the space left in Case XI. at the end of the Leadhills series. Hence the minerals of Strontian are here placed in immediate sequence to those of Leadhills.

Deposits of lead-ore near the little village of Strontian, in Argyllshire, were opened up at the beginning of the eighteenth century, and continued to be worked for rather more than 150 years. The ore occurred in veins, coursing through gneissose rocks, near their junction with the granite. Nos. 1505 and 1506 are samples of the *galena*, and many other specimens will be found in Wall-case 45. The museum is fortunate in possessing a rather large series of the Strontian minerals, principally from Bellsgrrove and Fee Donald Mines, presented by the late Sir James Miles Riddell, Bart., at the close of the Great Exhibition of 1851, where they had been exhibited.

In Section I. of the Horse-shoe Case are several examples of the *Calcite* from the Strontian lead-lodes, whilst in the case now under notice the species is represented by Nos. 1507 and 1508. One of these specimens shows the calcite in the form of "Slate spar," or *Schieferspath*—the tabular habit being determined by development of the basal pinacoid. The opaque white plates of this spar are seated on brown calcite, which is crystallized in obtuse rhombohedra, deeply striated and marked by dark radiating lines running along the short diagonals of the rhombs. *Barytes* also occurs in the vein-stone of the Strontian lead-lodes.

\* *Journ. Chem. Soc.*, vol. lv. (1889), p. 95.

† "Minerals New to Britain." *Min. Mag.*, vol. v. (1884), p. 22.

The village of Strontian is famous for having given its name to the element *strontium*. This metal occurs here in the form of the carbonate, known as *Strontianite*. It appears that the mineral was found as far back as 1764, and was at first regarded as carbonate of baryta. But in consequence of its property of imparting a reddish colour to flame it was suspected by Crawford, in 1790, to contain a new earth—a suspicion independently expressed by Cruikshank, and soon afterwards confirmed by Dr. Hope, of Edinburgh, who in 1792 determined the existence of a peculiar substance which he named after the *Strontian spar* in which it was discovered. The metal strontium was isolated by Davy in 1808.

Strontianite is here represented by Nos. 1509 and 1510, whilst the visitor is referred for other and larger specimens to Section G of the Horse-shoe Case. Distinct crystals are rare, but the mineral usually occurs in fibrous masses, the colour of which is sometimes pale green as in No. 1509, sometimes dark brown as in No. 1510. Strontianite is an orthorhombic species, isomorphous with witherite and aragonite. The mineral frequently contains barium, partially replacing the allied strontium.\* Just as witherite may be converted into barytes by the action of certain sulphates, such as those resulting from decomposing pyrites, so strontianite may be altered to celestite; and it is not surprising, therefore, to find that this species occasionally, though rarely, occurred at Strontian.

The remaining specimens in this Case represent two rather rare and interesting species, known as brewsterite and harmotome—minerals belonging to the group of hydrous silicates termed *zeolites*, to which attention will be specially directed in the description of Case XII. (p. 215). Nos. 1511 and 1512 show the *Brewsterite* in small brilliant crystals of prismatic habit, belonging apparently to the monoclinic system. The crystals are striated longitudinally, by repeated twinning, and present a pale yellowish brown colour. In No. 1512 the crystals are seated on strontianite. The mineral is a hydrous silicate of aluminium, strontium, barium and calcium, and may be regarded as a kind of heulandite (p. 217) in which calcium is partly replaced by strontium and barium. It was found chiefly in the Bellsgrrove lead-mine, and was described by Mr. Brooke, who named it after Sir David Brewster (b. 1781, d. 1868).

Although the zeolites are characteristic minerals in the cavities of eruptive rocks, they also occur to a limited extent in certain mineral veins. This is notably the case with *Harmotome*, which occurs typically in the silver-lead veins of Andreasberg, in the Hartz, as also in the lead-lodes of Strontian, especially in the old Bellsgrrove Pit. It is a zeolite which, like brewsterite, contains barium, but, unlike brewsterite, no strontium. The mineral crystallizes, it is generally believed, in the monoclinic system, but always in twins; and a characteristic habit is that of two complex sub-individuals interpenetrating, so as to produce a cruciform

\* “Analysis of a sample of Strontianite, from Strontian, Argyllshire.” By W. Ivison Macadam. *Min. Mag.*, vol. vi. (1886), p. 173.



group, whence the name "*cross stone*," which is sometimes applied to this species. The crystals from Strontian are bold and sharply defined, often of opaque white colour. The small colourless crystals of harmotome are sometimes distinguished as a variety under the name of *Morvenite*, a name derived from a locality in Argyllshire. The characters of the species are well represented by the specimens Nos. 1513 to 1516. Some of these show the harmotome associated with calcite, and it occurs also in companionship, as might perhaps be expected, with the other barium-bearing minerals, barytes and brewsterite.

The zeolites in the veins at Strontian may have been derived from the alteration of the feldspars in the neighbouring granitic rocks; but although certain feldspars contain barium the source of this element is more likely to be explained by reference to the barytes which occurs in the lodes. As Mr. Goodchild remarks, harmotome is one of the latest formed minerals in the veins at Strontian. It is suggested by this authority that the rocks of Strontian may have been covered by Tertiary basalts, and that the metalliferous minerals may have been introduced into fissures by the uprise of thermal waters towards the close of the volcanic period. The zeolites are probably of subsequent formation.\*

---

\* "The Natural History of Scottish Zeolites and their Allies." *Trans. Geol. Soc. Glasgow*. Supplement, vol. xii., 1903.

---

## CASE XII.

## DIVISION 1.

## MINERALS OF SCOTLAND.

## MINERALS OF THE MIDLAND VALLEY.

(Nos. 1517 to 1560.)

Many of the eruptive rocks which are so extensively developed in the great Midland Valley of Scotland yield various minerals of secondary origin, especially zeolites, of which a representative collection is here exhibited. Such minerals occur usually in the vapour cavities of the vesicular lavas, chiefly of andesitic type, which are referable to the early part of the Carboniferous period. Most of the specimens are from the volcanic rocks of the Clyde plateau—some from the south side of the estuary, notably from Boylestone Quarry in Renfrewshire, and others from the Campsie and Kilpatrick Hills, on the north.\*

In addition to the zeolites, a few other minerals occur in these ancient lavas. No. 1517 is a specimen of the *Native Copper* occasionally found in Boylestone Quarry, near Barrhead. This example, presented by Mr. Graham of Craigallian, shows the metal as a brilliant film on a joint-plane of the rock, as though electro-deposited on the wall of a fissure. Mr. Goodchild has suggested that in such cases the metal may have been dissolved out of the eruptive rock through which it was disseminated, and reduced perhaps from the state of carbonate by decomposing organic matter.† He also points out that in this quarry the native copper occurs occasionally as enclosures in calcite, and that the crystals of calcite are then more than usually complex in form. The metal is likewise found here in association with prehnite, to which it sometimes imparts a brown colour.

The association with prehnite and calcite rather recalls the conditions under which native copper occurs in the amygdaloidal diabase of the great copper-mining region of Lake Superior, where the metal is associated with these and other secondary minerals, including various zeolites. It is supposed that here the copper has

---

\* For a description of the rocks of this district see Sir Archibald Geikie's work: "The Ancient Volcanoes of Great Britain." London: 1897, vol. iv., p. 379. Caps. xxiv. and xxv. are devoted to a detailed description of the Carboniferous volcanic plateaux of Scotland. For a full description of the zeolites consult Mr. Goodchild's paper cited above.

† "The Scottish ores of Copper in their Geological Relations." *Rep. Brit. Assoc.*, Glasgow, 1901, p. 647.



been reduced from cupriferous solutions by the action of substances containing iron in the ferrous state, such as the augite and the magnetite of the eruptive matrix.\* S  narmont showed long ago that copper-bearing solutions were readily reduced by being moderately heated with various oxidisable bodies.

Possibly the formation of native copper in the narrow crevices of rocks may receive illustration from Prof. Becquerel's experiments on electro-capillary action. He obtained deposits of metallic copper by allowing a cupric solution, like the nitrate, and a solution of sodium sulphide to react on each other by very slow diffusion in capillary spaces.†

As metallic sulphides are rather uncommon in amygdaloidal rocks, the occurrence of the rare sulphide of cadmium, with prehnite, in the Carboniferous lavas of Renfrewshire, is peculiarly interesting. This compound, forming the species called *Greenockite*, is represented by Nos. 1518 to 1520—five specimens from the original locality near Bishopton. It was in piercing the hard rock to form the long tunnel at this part of the Glasgow and Greenock Railway that the mineral was originally brought to light. It was described as a new species by Prof. Jameson, who named it after Lord Greenock, afterwards Earl Cathcart (b. 1785, d. 1859) by whom it had been detected.‡ The crystals were measured by Mr. Brooke, and analysed by Prof. Connell.§

Greenockite, as seen in the specimens here exhibited, occurs in small sharply-defined hemimorphic crystals, referable to the hexagonal system, and presenting a yellow colour, inclining to orange, with a brilliant, rather adamantine lustre. The mineral was originally mistaken for zinc-blende. Sulphide of cadmium does indeed occur in certain kinds of blende known from the Bohemian locality as *Przibramite*; and the two sulphides—those of zinc and cadmium—belong to an isodimorphous group. Hexagonal sulphide of zinc, in crystals much like those of Greenockite, constitutes the species distinguished by Friedel as *W  rtzite*. It is notable, too, that Sidot obtained zinc sulphide in hexagonal crystals by strongly heating either the artificial amorphous sulphide or common blende.|| Sidot's hexagonal blende is used for fluorescent screens in experiments on radio-activity.

The specimens numbered 1521 to 1524 are excellent examples of the geodes formerly found in the andesitic lava so largely quarried as "whinstone" at the back of Gourrock, near Greenock, in

\* "The Deposition of Copper by Solutions of Ferrous Salts." By H. C. Biddle. *Journ. Geol.*, vol. ix. (1901), p. 430.

† "Note sur les r  ductions m  talliques dans les espaces capillaires." *Comptes Rendus*, vol. lxxxii. (1876), p. 354.

‡ "Notice of Greenockite, a new Mineral Species of the order Blende." *Ed. New. Phil. Journ.*, vol. xxviii. (1840), p. 390.

§ "Chemical Examination of Greenockite, or sulphuret of Cadmium." By Arthur Connell. *Ibid.*, p. 392.

|| "Recherches sur la cristallisation de quelques sulfures m  talliques." *Comptes Rendus*, t. lxii. (1866), p. 999.

Renfrewshire. These drusy cavities were lined with crystals of *calcite*, *quartz* and *fluorite*. It will be noted that some of the calcite is tinted pink. An analysis of the pink calcite of Gourrock yielded Dr. Heddle 4·27 per cent. of manganous carbonate.\* The fluor-spar occurs in dark purple cubes, seated on the calcite, and it has been remarked that of all minerals in these druses the fluor is the latest formed.† It is notable that fluor-spar, so common in many parts of England, is decidedly rare in Scotland.

A rather extensive series of specimens, mostly from the Kilpatrick Hills (Nos. 1525 to 1552) illustrates the group of *Zeolites*, which are developed in exceptional beauty and variety in some of the Carboniferous lavas of the Clyde basin. The zeolites constitute a well-marked group of crystallised hydrated silicates, all containing aluminium, and most of them likewise containing either calcium or sodium, or in some cases both. Usually the zeolites appear to be secondary products, resulting mostly, if not exclusively, from the alteration of various felspathic and felspathoid minerals, especially the lime-soda felspars. Some have indeed been regarded as hydrated plagioclase. Connected with the presence of water is the fact that these zeolites are softer and less dense than the felspars, their specific gravity being about 2·2. The zeolites are rather unstable minerals, and it is sometimes noticed that one species passes into another.

It was observed by Cronstedt, in the early days of mineralogy, that most of these minerals intumescence when heated before the blow-pipe, whence they came to be called zeolites, or “boiling stones.” They are readily decomposed by acids, and, as first noticed by Bergmann, many of them when so treated gelatinise.

The condition in which the water occurs in the zeolites has been the subject of much discussion. In some cases it may occur partly as water of crystallisation and partly as hydroxyl belonging to the silicate molecule. The water of crystallisation appears to be very loosely held, being readily lost and regained, according to the dryness or the humidity of the surrounding medium. With the loss of water, the optical properties of the mineral are affected. The dehydrated zeolites may in certain cases be caused to absorb other substances than water, even various colouring agents, as shown by the experiments of Friedel.

It is notable that certain zeolites occur in the red clays of the deep-sea floor, as described by Sir John Murray and the late Prof. Renard. Notwithstanding the low temperature prevailing in abyssal waters, certain chemical reactions go on, which result in the decomposition of the basic volcanic rocks by means of sea-water, and the formation of zeolitic minerals, like phillipsite. The origin of such minerals is therefore similar to that of the zeolites in amygdaloidal rocks, although the conditions of occurrence seem so

\* *Trans. Roy. Soc., Edin.*, vol. xxvii. (1876), p. 499.

† “Miscellaneous Notes on Chemical Geology.” By Wallace Young. *Trans. Geol. Soc. Glasgow*, vol. iii. (1871), p. 31.



different. Moreover Prof. Lacroix has shown that in the Pyrenees zeolitic minerals are in course of formation at the present day by the decomposition of rocks under the influence of water from melting snow.\* Such an origin however, seems to be rather exceptional for the zeolites, and in most cases such minerals were probably formed at rather an elevated temperature.

By prolonged action of thermal waters on the concrete at certain Roman stations in France, several species of zeolites have been produced. Zeolites also occur in mineral-veins, especially in those which carry lead, with calcite in the gangue; and their occurrence in the lead lodes of Strontian under these conditions has already been noticed (p. 211).

It was shown by Wöhler, in 1848, that powdered apophyllite is soluble in water, when heated in a closed tube to  $180^{\circ}$  C.; and C. Doelter has since found that most zeolites dissolve in pure water, at temperatures between  $120^{\circ}$  and  $160^{\circ}$ , whilst the solubility is still more marked when carbonic acid is present. On cooling, the zeolite separates from the solution in crystals. Sir A. Geikie believes that in many cases the amygdales, or mineral-kernels in lavas which were once vesicular, may have been deposited before the rock had completely cooled,†—a view also held by Mr. Harker with regard to the zeolites of Skye (p. 221).

The mineral called *Prehnite*, of which a rather fine suite of specimens is here exhibited (Nos. 1525 to 1531), can hardly perhaps claim a place among the true zeolites, inasmuch as all the water seems to be basic, so that it is not strictly a hydrated silicate; and further it is only slightly attacked by acids, whilst its hardness and density are greater than in typical zeolites. Nevertheless, it often occurs in association with the zeolites and was formed apparently under similar conditions, being found in amygdaloidal rocks, as well as in veins. It frequently forms botryoidal and mammillated masses, crystalline in structure, and usually of green colour, though sometimes brown.‡ The association of prehnite with copper is rather characteristic, and the brownish tint is sometimes referable to minutely disseminated particles of the native metal, whilst the green colour has been referred in some cases to the presence of chrysocolla, in others to chlorite or perhaps to epidote. Prehnite was a very common mineral at Boylestone Quarry in Renfrewshire, and at Bowling Quarry in Dumbartonshire.

Associated with the prehnite, as shown by some of these specimens, there commonly occurs the zeolite called *Thomsonite* (Nos. 1532, 1533). This is a lime-soda silicate, generally in white or

---

\* "Sur la formation de zeolites sous l'influence du ruissellement superficiel" *Comptes Rendus*, t. cxxiii. (1896), p. 761.

† "The Ancient Volcanoes of Great Britain." Vol. ii., p. 189. The reference is here to the amygdaloidal rocks of Tertiary age.

‡ The character of these curved aggregates of prehnite crystals has been studied by Mr. Goodchild, in his paper on "The Natural History of the Scottish Zeolites" already quoted.

colourless crystals, of acicular or columnar habit, arranged in radiating groups. Among the other minerals exhibited here may be mentioned the delicate fibrous zeolite known as *mesolite* (No. 1534). The commonest of the fibrous zeolites is termed *natrolite*; and probably the mineral known as *galactite* (Nos. 1535, 1536) is an isomorphous mixture of natrolite and scolecite, whilst the zeolite named *crocalite* (No. 1537) may also be regarded as a variety of natrolite.

Of all the zeolites in this case the most attractive to the eye are the brick-red crystals of *Stilbite* (Nos. 1538 to 1541) and of *Heulandite* (Nos. 1542, 1544).\* These two minerals have much in common. Both are lime-zeolites, apparently crystallising in the monoclinic system. The stilbite not infrequently occurs in sheaf-like aggregates of crystals, whilst the heulandite has quite a characteristic habit, the crystals being perhaps best described as coffin-shaped. The pearly lustre on the cleavage planes of the heulandite is worthy of notice. The red colour has been referred to the presence of included scaly crystals of göthite, or oxide of iron; but Dr. Haughton regarded the colour of some red heulandite which he examined as due to the molecular condition of the mineral.† Very notable is the specimen, No. 1540, showing the red stilbite embedded in a large cleavage rhombohedron of calcite, where the stilbite is obviously the mineral of earlier formation. "There may be some connection," says Mr. Goodchild, "between the colour of the stilbite and the lithological nature of the rock from which it has been derived." The brick-red minerals occur in the andesitic lavas of Stirlingshire and Dumbartonshire, and are labelled in most collections as coming from the Campsie Hills.‡ The red heulandite has been also recorded from Little Cumbrae.§

But little need be said about the other zeolites shown here. *Analcite*, or *Analcime* (No. 1548), is exceptional among zeolites in its crystallisation, inasmuch as it occurs in icositetrahedra, resembling those of leucite—a mineral to which it seems to be related. The crystals of analcite are remarkable for their optical behaviour. The mineral called *Cluthalite* (No. 1545) is perhaps an altered analcite. *Chabazite* (No. 1546) occurs well crystallised in rhombodehra, which have a cube-like appearance, rather suggestive of crystals of fluor. Twin crystals are not infrequent. The most unstable of all the zeolites is the efflorescent mineral which received the name of *Laumontite* (No. 1547) after an old French mineralogist, Gillet de

\* The mineral here called stilbite is termed by many Continental mineralogists *Desmine*, whilst our heulandite is often known as *Stilbite*. Some of the zeolites described above as "apparently monoclinic" may really be anorthic.

† *Journ. Geol. Soc., Dublin*, vol. viii. (1860), p. 234.

‡ See "On New Localities for Zeolites." By Prof. M. Forster Heddle. *Trans. Geol. Soc. Glasgow*, vol. ix. (1893), p. 72. The author failed to find them in the Campsie Hills.

§ "A visit to the Island of Little Cumbrae, with some notes on its Minerals." By James Neilson. *Ibid.*, p. 373.



Laumont. *Edingtonite* (No. 1549) is rather notable inasmuch as it contains barium, and to this extent bears some relation to the zeolites already described as harmotome and brewsterite (p. 211).

Several specimens of *Pectolite* are here exhibited (Nos. 1550 to 1552). This mineral can hardly be regarded as a true zeolite, yet it occurs under very similar conditions, being often found as a secondary mineral in the vapour-vesicles or in the fissures of old basic lavas. It generally forms tough, radiated masses, composed of fibres which are often silky in lustre. In certain cases it is pseudomorphous after analcite. Some of the specimens, of rather greenish-grey colour, are from the Ratho quarries, near Edinburgh, and have hence been described under the name of *Ratholite*. They occur in an intrusive sheet of dolerite, in the Lower Carboniferous strata.

Following the zeolitic group of minerals comes a small series illustrating the characters of Scottish *agates*. (Nos. 1553 to 1560). Like zeolites, the agates occur usually in the steam cavities of eruptive rocks, as secondary minerals resulting from the decomposition of the matrix; like zeolites, again, they occur occasionally in veins. In Scotland the best agates are derived from the andesitic lavas of the Lower Old Red Sandstone; and Mr. Goodchild has remarked that since they occur in the conglomerate of the Upper Old Red Sandstone, some at least must have been formed within the limits of time represented by these rocks. On the disintegration of the matrix the agates may weather out, and be found loose in the soil as "Scotch pebbles." The polished sections of pebbles, Nos. 1553 to 1557, are from near Montrose.

An agate consists of alternating layers of various siliceous minerals, especially chalcedony, but including also cachalong, quartz and opal. These minerals have been deposited from siliceous solutions, which gained access to cavities in the old lava. It generally happens that the walls of the cavities are immediately lined by a deposit of the green earthy minerals known as *celadonite* and *delessite*—minerals which have resulted from the decomposition of augite, or some other ferro-magnesian mineral in the eruptive rock. Upon this "priming," to borrow Mr. Goodchild's expressive term, the chalcedony may be deposited either directly or with an intervening layer, which, according to Dr. Heddle, may be zeolitic. Gelatinous silica was deposited in the interior of the cavities, in most cases equally around the whole internal space, the material having secured adhesion to roof and wall as well as to the floor. Successive deposits, more or less variable in character, were thrown down in regular sequence, layer upon layer, so that a transverse section of an agate displays a zonal pattern due to the cut edges of the deposits.

Many agates exhibit tubular orifices or cracks which appear to have served as channels for the passage of the siliceous solutions. They were formerly regarded as inlets of infiltration, but G. Lange many years ago suggested that they might be channels of egress, through which the solution, after deposition of more or less of its siliceous burden, had been expelled. Dr. Heddle, who made a

special study of agates, also regarded these channels as "tubes of escape," believing that the solution from which the silica had been precipitated passed out on the introduction of a stronger solution, by osmotic action.\*

In some cases, as seen in No. 1556, the siliceous minerals may form horizontal deposits on the floor of the cavity, producing an *onyx*; in other cases the deposits may hang from the roof of the cavity as stalactitic chalcedony; or they may be deposited over and around rugosities of the walls and floors, forming concentric deposits, circular on section, known as *eye agate*. In the tray No. 1558 are two eye-agates from the Path of Condie in Perthshire; No. 1559 is a specimen of *moss-agate* from Dunbar, and No. 1560 a polished slab of red *jasper* from Campsie Glen. A large collection of polished specimens of Scottish agates and jaspers will be found in Sections P. and  $\Phi$  of the Horse-shoe Case; and hence it has not been deemed necessary to exhibit a large number here. The Ludlam collection was far from rich in examples of such minerals.

#### MINERALS OF THE HIGHLANDS.

(Nos. 1561 to 1572.)

For convenience of space the minerals from the lead-mines of Strontian, in Argyllshire, have been placed in Case XI., in juxtaposition with the ores of the Leadhills district. Comparatively few other minerals from the Highlands of Scotland are exhibited in this collection. The specimens numbered 1561 and 1562 are good examples of the red variety of epidote, named by Sir David Brewster, *Withamite*.† This mineral occurs in the altered lavas of the Lower Old Red Sandstone of Glencoe, in Argyllshire, where it was first detected in 1824 by Henry Witham. Brewster observed its remarkable dichroism; and in recent years its optical characters have been fully studied by Prof. Lacroix, who has pointed out their relation to those of epidote and piedmontite—the latter a manganese-epidote.‡ Dr. Heddle found in the Withamite of Glencoe 0·138 per cent, of manganous oxide.§ According to Mr. Goodchild the mineral has resulted from the alteration of celadonite, itself probably due to the decomposition of the pyroxene of the eruptive rock in which it occurs. Withamite has recently been found by Mr. Muff, of the Geological Survey, in a dyke at the Meeting of the Three Waters.||

\* On Scottish agates see Dr. Heddle's paper "On the Structure of Agates," *Trans. Geol. Soc.*, Glasgow, vol. xi., part ii. (1900), p. 153; also his "Mineralogy of Scotland," vol. i. p. 58; and Mr. Goodchild's paper "On the Genesis of some Scottish Minerals," *Proc. Phys. Soc., Edin.*, vol. xiv. (1899), p. 191.

† "Description of Withamite, a new mineral species found in Glencoe," *Edin. Journ. Sc.*, vol. ii. (1825), p. 218.

‡ "Propriétés optiques de la Withamite." *Bull. Soc. Min. Fr.*, vol. ix. (1886), p. 75.

§ "Minerals new to Britain." *Min. Mag.*, vol. v. (1884), p. 15.

|| "Summary of Progress" for 1903, p. 55.



The great granite masses of the Central Highlands have yielded a few notable minerals, such as the well-known *Cairngorm*. This is a variety of quartz, of smoky or yellow tint, named after the mountain in Banffshire, where it occurs in drusy cavities in veins of granite running through the main mass. In order to obtain the cairngorm, pits were formerly dug in the disintegrated part of the granite, and the mineral was found as loose crystals in the kaolinised material. Rolled crystals occurred in the bed of the River Avon.

As Mr. Cunningham Craig remarks, the veins represent intrusions of the acid magma into fissures of contraction in the granite, and the quartz has probably crystallized from highly siliceous solutions which filled the cavities in the veins.\*

In addition to the specimens shown here (Nos. 1565 to 1568), a fine series of cairngorms, including many cut specimens of great beauty, will be found in Section N. of the Horse-shoe Case. It should be noted that brown and yellow quartz is sometimes improperly called "topaz," or "smoky topaz," a practice not uncommon in trade and even in scientific writings.

The fine specimen of smoky quartz, No. 1568, presented by G. Barrow, Esq., is from Banchory in Aberdeenshire.

Associated with the smoky quartz of the Cairngorm district, and occasionally occurring in the bed of the Avon, were formerly found crystals of true *Topaz*. Some of the largest have been obtained from Benabour (Beinn a' Bhuid), in the Aberdeenshire part of the granite mountains, whence several specimens, each more than a pound in weight, have been recorded. The collection includes some excellent examples of Scottish topaz (Nos. 1569 to 1572), illustrating the crystalline forms, the characteristic basal cleavage and the typical tints of the mineral. Most of the specimens are of pale blue colour, inclining in certain parts to a reddish brown tint, whilst some are practically colourless. *Beryl* occasionally accompanies the topaz of the granite of the Grampians, as is the case in so many other localities. Reference has already been made (p. 25) to the probable origin of topaz in granitic rocks by pneumatolytic action.

Two specimens of *Rutile*, the most common of the three species of titanium dioxide, are here exhibited. This mineral not infrequently occurs in quartz veins in the crystalline schists. No. 1563 from Killin, in Perthshire, shows the rutile in reddish-brown acicular crystals penetrating quartz; whilst in No. 1564 it occurs as a stout prismatic crystal, longitudinally striated, associated with muscovite and quartz. It is notable that in the latter specimen the crystal has been bent and broken, and the fragments cemented together by quartz. Prisms of tourmaline sometimes exhibit similar fracture and cementation.

Brief reference may here be made to the recent discovery, by the Geological Survey, of *Cassiterite* in the granite gneiss

\* "On Cairngorms." By E. H. Cunningham Craig, B.A. *Rep. Brit. Ass.*, Glasgow, 1901, p. 654.

of Carn Chuinneag in Ross-shire.\* The discovery is of special interest, inasmuch as tin-stone, though found in England and Ireland, had not previously been known to occur in Scotland. It is notable that the cassiterite is here found under exceptional conditions, being associated with much magnetite but without tourmaline, and with but little quartz. The mode of occurrence is at present (1904) fully illustrated in a table case, placed near the collection of Scottish Minerals.

### MINERALS OF THE WESTERN ISLES, ETC.

(Nos. 1573 to 1584.)

Many of the basic lavas of Tertiary age, which occur in the Western Isles of Scotland, spreading out as extensive plateaux or rising into tabular hills, enclose in their vesicular cavities a number of zeolitic minerals similar to those already described as occurring in the older volcanic rocks of the Midland Valley. Such minerals are represented here by a small suite of characteristic specimens from the Isle of Skye, principally from the rocks of Storr, in the northern part of the island.

According to Mr. Harker, who has made an elaborate study of the Tertiary igneous rocks of Skye, the minerals of the amygdaloidal basalts were formed from the alteration of the rocks not by ordinary weathering but by the action of heated water, probably of volcanic origin, soon after the extrusion of the lava: indeed, their formation may represent the final phase of volcanic activity.† It is interesting to note that, by thermal metamorphism, the zeolites have in some cases been transformed to felspar—apparently a reversion to their original condition, due chiefly to loss of water.

Among the zeolites of Skye here exhibited are specimens of *Stilbite* (Nos. 1573 to 1576), showing the mineral in white crystals, with pearly lustre on the cleavage faces, the crystals being, in some cases, aggregated in sheaf-like groups, and in others displayed in radiating forms. *Laumontite* is illustrated by No. 1577, where the white efflorescent mineral is partly coating crystals of stilbite. No. 1578 is a specimen of *Chabazite*, in which the mineral is seen in white rhombohedral crystals, rather recalling the general aspect of fluor-spar. *Analcite*, or *Analcime*, is represented by No. 1579, which shows the sharply defined white icositetrahedral crystals so characteristic of this species. According to Dr. Heddle the form in the Tertiary traps of the Hebrides is invariably the simple icositetrahedron, whilst in the palæozoic lavas of Scotland the species sometimes shows faces of the cube.‡

\* "Summary of Progress" for 1903, p. 58.

† *Mem. Geol. Surv.*, "The Tertiary Igneous Rocks of Skye." By Alfred Harker, M.A., F.R.S., with Notes by C. T. Clough, M.A., 1904.

‡ "On Analcime with New Forms." *Trans. Edin. Geol. Soc.*, vol. vii. (1899), p. 241. Also "Mineralogy of Scotland," vol. ii., p. 103.



No. 1580 is a specimen of *Mesolite*, in which white needle-like crystals spring from the walls of a drusy cavity in basalt, whilst No. 1581 is an example of the lime zeolite known as *Gyrolite*. With the zeolites, though perhaps in strictness hardly belonging to the group, is placed an example of *Pectolite* (No. 1582), a mineral of which a brief notice has already been given (p. 218).

The specimen of *Chlorophacite* (No. 1583) is in an amygdaloidal basalt from the Isle of Rum. This mineral appears to be a hydrated basic silicate of iron, magnesium and calcium, derived from the decomposition of the ferro-magnesian silicates in the lavas, and forming in their vesicular cavities an amorphous substance of dark green, or in some cases almost black colour.

The series of Scottish minerals is brought to a close by a specimen of *Chromite* or *chromic iron-ore* (No. 1584) from Unst, one of the Shetland Islands, where it occurs in a matrix of serpentine. This mineral, which is a member of the 'spinel group' and is rather variable in composition, has been worked commercially in Shetland as a source of chromium and its compounds. The chromite probably became segregated from a basic eruptive magma, through which it was originally diffused.

---

## DIVISION 2.

### MINERALS OF IRELAND.

#### MINERALS OF LEINSTER.

(Nos. 1585 to 1600.)

The collection of Irish minerals, though not large, is fairly representative, and gives within narrow limits a general notion of the mineralogy of Ireland. According to Mr. H. J. Seymour,\* the number of mineral species known to occur in Ireland is about 115.

In the arrangement of this Collection, the minerals of each of the four provinces are grouped together. For a concise description of the geology of Ireland, the visitor may be referred to the Guide to the Survey Collections in the Dublin Museum of Science and Art.†

Among the minerals of Leinster the most interesting are the specimens of *Native Gold* from Croghan Kinshelagh, in County Wicklow (Nos. 1585 to 1587). This mountain is part of an elevated tract rising to a height of 1987 feet above sea-level, and consisting mainly of slaty rocks of Lower Silurian (Ordovician) age, associated

---

\* "Preliminary List of the Minerals occurring in Ireland." By Henry J. Seymour, B.A. *Rep. Brit. Assoc.*, Belfast, 1902, p. 598. Also Supplementary List in *Rep. Brit. Assoc.*, Southport, 1903, p. 671.

† "Guide to the Collections of Rocks and Fossils belonging to the Geological Survey of Ireland." By A. McHenry, M.R.I.A., and W. W. Watts, M.A., Dublin, 1898

with intruded masses of certain eruptive rocks. The gold occurred in the valley gravel of several streams, principally in that of the Gold Mines River.\*

It has been suggested that the alluvial deposits of this district probably supplied much of the gold used in the ancient Keltic ornaments of Ireland. In modern times attention was prominently directed to the Wicklow area by the accidental discovery of gold there in the year 1795. Crowds of peasants were attracted to the diggings, and it is said that gold to the value of several thousand pounds was obtained by desultory working, before the Government commenced systematic exploration.† The official workings were discontinued at the outbreak of the Rebellion in 1798, but were renewed in 1801, when tunnels were driven into the mountain, in quest of the quartz reefs, which were supposed to have supplied the detrital gold; but these explorations were unattended with success.

The largest nugget ever found in the Wicklow workings, represented by a model in Wall-case 14, reached the weight of about 22 ounces. Its remarkable story was told by the late Prof. V. Ball.‡ The specimens in the Case under description include several samples of the alluvial gold, of which No. 1587 is peculiarly interesting, inasmuch as it shows the metal in a water-worn pebble of iron-stained quartz, and consequently indicates the nature of the original matrix.

The alluvial gold of Wicklow was associated with magnetite, and to a less extent with cassiterite and wolfram, thus recalling the conditions under which gold occurs in Cornwall. Other minerals were also occasionally found, such as molybdenite, galena, chalcopyrite, corundum, zircon and spinel, whilst the existence of platinum, though not definitely proved, was suspected.§ The origin of the minerals was probably connected with the intrusion of the eruptive rocks into the slates.||

No. 1588 is a specimen of granular *magnetite* from Ballycoog, in County Wicklow, where workings were at one time carried on to a limited extent upon veins of this mineral, coursing through the slaty rocks of the district.

The mineral deposits of Wicklow, although yielding but little at the present time, have been in their day more important than

\* For the geological structure of the district, and for bibliography relating to the Wicklow gold mines see "Explanatory Memoir to accompany sheets 138 and 139 of the Geological Survey of Ireland." By Edward Hull, LL.D., F.R.S. 1888.

† The workings formed the subject of a comic opera, played at Covent Garden under the title of "The Lad o' the Hills; or the Wicklow Gold Mines."

‡ "On the gold nuggets hitherto found in the County Wicklow." *Sci. Proc. Roy. Dublin Soc.* (new series), vol. viii. (1895), p. 311.

§ "On the Minerals of the Auriferous Districts of Wicklow." By William Mallet, Esq. *Journ. Geol. Soc., Dublin*, vol. iv. (1851), p. 269.

|| For the occurrence of Irish gold see paper by the late Gerrard A. Kinahan "On the mode of occurrence and winning of gold in Ireland." *Sci. Proc. R. Dub. Soc.* (n.s.) vol. iii. (1883), p. 263.



those of any other county in Ireland. The metalliferous minerals—including ores of iron, copper and silver-lead—are confined chiefly to a great band, or “mineral channel,” stretching from Wicklow in a south-westerly direction to Ovoca, and thence to Croghan Kinshelagh, a distance of fourteen or fifteen miles.\* The ore now worked is for the most part iron-pyrites, known generally as *Sulphur-ore*. Previously to about the year 1840 the pyritic deposits of Ovoca were not worked for sake of their sulphur, but some of the ore-bodies were wrought as copper-mines. Much of the pyrites, indeed, contains a small proportion of copper, thus resembling the cupriferous pyrites which occurs in enormous deposits in Spain and Portugal. In recent years most of the Irish ore has been beaten out of the market by Spanish pyrites. No. 1589 is a specimen of copper-bearing pyrites from Ballymurtagh Mine, in the Vale of Ovoca.

In the year 1902 the mines of Wicklow yielded 1,617 tons of pyrites, or “sulphur-ore,” and 444 tons of cupreous pyrites, containing about 2 per cent. of copper.

In addition to the copper in the iron pyrites, copper also occurs to a limited extent, as *chalcopyrite*, forming distinct “bunches” of ore: *black copper ore*, consisting chiefly of the oxide, was formerly found in the shallow workings, sometimes in workable quantity, and *native copper* was not unknown.

Large quantities of *copper precipitate* were formerly produced at the Ovoca Mines, by means of scrap-iron which effected the reduction of the metal from the coppery water that drained through the pyritic deposits. The process was similar to that already noticed in connection with the production of “cement copper” in Anglesea (p. 127). An interesting historical account of the precipitation processes, as carried on in Ireland and on the Continent, will be found in the late Sir Warrington Smyth’s memoir on the mines of Wicklow.†

Although no lead-ore is now worked in Wicklow, this mineral was formerly the object of extensive exploration in certain parts of the county. No. 1590 is a sample of *galena* crystallised on quartz, from the old Lukanure mines at Glendalough. The lodes yielding the lead-ores of this district run through granite, in a direction nearly north and south. Some of the other lead veins, as at Glenmalure, occur near the junction of the granite with the neighbouring mica-schist. A specimen of green *pyromorphite* from Glenmalure is here shown (No. 1593), and there are also two specimens of *cerussite* (Nos. 1591 and 1592), in further illustration of the secondary ores of lead. Both specimens show the cerussite

---

\* For a description of the metalliferous minerals of Ireland, see Mr. G. H. Kinahan’s comprehensive paper on “Irish Metal Mining” in *Scient. Proc. Roy. Dublin Soc.*, new series, vol. v. (1886), pp. 200–317.

† “On the mines of Wicklow and Waterford.” *Records of the School of Mines*, vol. i, part iii. (1853), pp. 349–412. See also “Notes on the Recovery of Copper from its solution in mine drainage, with special reference to the Wicklow Mines.” By Philip Argall and Gerrard A. Kinahan. *Sc. Proc. Roy. Dub. Soc.*, new series, vol. iii. (1883), pp. 302–328.

in good crystals, and in No. 1592 these crystals are seated on a matrix of decomposed galena, clearly suggesting the origin of the carbonate as an alteration-product of the original ore.

Professor J. Joly has recorded the occurrence of harmotome in the gangue of the Luganure lode, where also fluor-spar, barytes, and strontianite occur, associated with galena, blende, pyrite and copper pyrites.\*

The mineral called *Kilmacooite*, represented by No. 1595, is a mixed sulphide, much resembling the so-called "blue-stone" of Anglesea. It has been regarded as an intimate mixture of galena and blende, and described by Dr. Tichborne as "an argentiferous galenitic-blende."† It generally contains, however, not only the sulphides of lead and zinc, but, also subordinately, and in variable proportion, those of iron, copper and antimony, with silver to the extent in some cases of eight ounces to the ton. Large quantities of the mineral were raised from the Kilmacoo lode, in the Connary Mine. According to Mr. Argall, the iron-pyrites in the main lode at the Magpie Mine graduated locally into kilmacooite.‡

The great mass of Leinster granite has yielded some interesting minerals, but these are scarcely represented in this Collection. The tray numbered 1596 contains some beautiful crystals of transparent quartz, of a delicate smoky tint, presenting the form which has led to its name of *Sceptre quartz*. In such crystals, which are found near Carlow, a slender six-sided prism is expanded towards the summit so as to pass into a stouter prism, which is capped by the hexagonal pyramid.

No. 1598 is an example of *plumose mica*, from near Dublin, showing the silvery muscovite gracefully spread out in feather-like forms.

The mineral named *Killinite*, from Killiney Hill, south of Dublin, where it was discovered in 1817, is represented by the specimen No. 1597. This mineral appears to have resulted from the alteration of spodumene, a species which is known to occur in the granite. According to the late Dr. Haughton "the so-called Killinite is an altered spodumene, from which the lithia has been washed out by weathering."§ It has long been known that *Beryl* occurs in the Leinster granite, and it has been found by Prof. Joly in the quarries of Glennullen, County Dublin.||

\*"On the occurrence of Harmotome at Glendalough, County Wicklow." By J. Joly, B.E. *Sc. Proc. Roy. Dub. Soc.*, new series, vol. v. (1886), p. 165.

†"On an argentiferous galenitic-blende at Ovoca." By C. R. C. Tichborne, LL.D. *Ibid.*, new series, vol. iv. (1885), p. 300.

‡"Notes on the Ancient and Recent Mining operations in the East Ovoca District." By P. H. Argall. *Ibid.*, new series, vol. ii. (1880), p. 211.

§"On the Mineralogy of the counties of Dublin and Wicklow." By the Rev. Samuel Haughton, M.D. *Journ. Roy. Geol. Soc. Irel.*, new series, vol. v., part iii. (1880), p. 43.

See also Dr. Galbraith's paper "On the different analyses of Killinite." *Journ. Geol. Soc. Dub.*, vol. vi. (1856), p. 165.

||"Notes on the Minerals of the Dublin and Wicklow granite." By J. Joly, B.E. *Sc. Proc. Roy. Dub. Soc.*, new series, vol. v. (1886), p. 48. See also Prof. J. P. O'Reilly in *Journ. R. Geol. Soc. Irel.* (n.s.), vol. vii. (1887), p. 69.



## MINERALS OF CONNAUGHT.

(Nos. 1599 to 1604.)

Among the ores which have been worked from time to time in this province, those of *iron* from the Connaught coalfield are perhaps the most important; but these ores are not at present represented in the Collection.

Ores of *lead* and *copper* have occasionally been the object of exploration in Galway, where lodes and other ore-deposits occur in the granitic and metamorphic rocks as well as in the Carboniferous Limestone. No. 1599 is a specimen of *copper-pyrites* from the Cregg Mine, in Oughterard. According to the Survey Memoir, by Mr. G. H. Kinahan, the mineral occurred in a strong lode bearing N. 66° W. and hading to the south.\* No. 1600 is a cleavage-piece of *galena*, boldly crystalline in structure, from the neighbouring mine of Clooshgareen, which was worked on a continuation of the Cregg lode. *Barytes* occurs with the lead ore at the Cloosh Mine, and is represented by two samples: in one of these, No. 1601, the mineral forms a snow-white crystalline mass, and in the other, No. 1602, it presents a translucent glassy appearance, with well-marked cleavage-planes. The specimen No. 1602 was presented by H. E. A. Young, Esq., whilst Nos. 1601 and 1602 were the gift of J. T. Darke, Esq.

In the year 1902 the province of Connaught yielded 463 tons of barytes, but this was raised in County Sligo. Large deposits of the mineral occur in the King's Mountain.

It is notable that *Native Sulphur*, quite a rare mineral in Britain, occurs in the Carboniferous Limestone of Oughterard. No. 1603 is an excellent specimen of this sulphur, in its matrix, contributed by the Geological Survey of Ireland. The sulphur occurs, in association with calcite and pearl-spar, lining geodes or drusy cavities in the limestone, and is occasionally found inside fossil shells. Mr. Kinahan has suggested that the sulphur of Oughterard may have been known in ancient times, since a river at this locality is named Owenriff—a word which means in English “Brimstone River.”†

Native sulphur may owe its origin, in many cases, to reduction from various sulphates, especially from gypsum, as already mentioned in connection with specimens from Nottinghamshire (p. 185). It may also be reduced from metallic sulphides, like pyrites and galena. Then again, natural waters, especially thermal springs, may contain sulphides, from which sulphur will be precipitated on exposure to the air, the deposition being facilitated by the action of carbonic acid and by organic agencies like bacteria.

Among the few Connaught minerals here exhibited is a specimen of *Rutile* (No. 1604) from the mica-schist of Cush-cum-Curragh, near Borrishdale, on the north of Clew Bay in County Mayo. This

\* *Mem. Geol. Surv. Ireland.* Explanation of Sheet 105 and part of Sheet 114. By G. H. Kinahan. 1869. p. 58.

† *Mem. Geol. Surv. Ireland.* Explanation of Sheet 95. By G. H. Kinahan and J. Nolan, 1870, p. 63.

specimen was presented by Spencer G. Perceval, Esq., by whom the mineral was discovered at this locality in 1868. It occurs in prismatic brown crystals, with vertical striations and other typical characteristics. The mineral was analysed by Prof. Emerson Reynolds, who noted the occurrence with it of small black crystals of the variety of rutile distinguished as *nigrine*.\*

## MINERALS OF ULSTER.

(Nos. 1605 to 1633.)

Several groups of minerals from different parts of the province of Ulster are exhibited in this Division of the collection. One small but interesting group represents certain minerals from the granites and crystalline schists of the highlands of Donegal. Among these the specimens of *Beryl* are especially noteworthy. According to Mr. R. H. Scott,† beryl occurs as an accessory mineral disseminated through part of the granite as well as in veins of quartz running along the joints. The large crystals of beryl exhibited here were obtained from Sheskinaroan, a little to the north of Dungloe, on the road to Anagary. One of the specimens, No. 1605, shows a six-sided prism of opaque white colour, in a matrix of pegmatite; whilst in the tray, No. 1608, are two specimens of beryl, more or less greenish in colour, and embedded in quartz. The Donegal beryl was analysed by Dr. Haughton.‡

By side of the beryls are exhibited several large crystals of *Garnet*. The garnets of Donegal occur both in crystalline schists and in altered limestone. The tray, No. 1609, contains two large brown rhombic dodecahedra, more or less eroded on the surface, and referable to the common species generally known as *Andradite*. Mr. Scott refers to loose crystals, frequently two inches in diameter, pitted by the action of sea-water, occurring on the beach at Toberkeen. In No. 1610 the garnet is associated with *Idocrase*, or *Vesuvian*, in brown bacillary forms. Such an association is by no means uncommon, especially in the contact-zone between limestone and crystalline rocks. Epidote and wollastonite occur in Donegal under similar conditions.§

The minerals exhibited here from the highlands of Donegal were obtained some forty years ago by Patrick Doran, a well-known collector who visited the wildest parts of Ireland in quest of minerals, and contributed materially to our knowledge of Irish mineralogy. In addition to these there is a specimen of *Cyanite* (No. 1611), from County Donegal, presented by J. Rhodes, Esq.

\*“ Note on Specimens of Rutile, from the County Mayo.” By J. Emerson Reynolds. *Journ. Roy. Geol. Soc. Dublin*, new series, vol. ii. (1871), p. 164.

† “ On the Mineral Localities of Donegal.” *Journ. Roy. Dub. Soc.*, vol. iv. (1866), p. 114; *Rep. Brit. Assoc.*, for 1863, p. 67.

‡ *Quart. Journ. Geol. Soc.*, vol. xviii. (1862), p. 417; *Rep. Brit. Assoc.*, Newcastle-upon-Tyne, 1863, p. 58.

§ For a geological description of N.W. and Central Donegal, see *Mem. Geol. Surv. Irel.* to accompany Sheets 3, 4, 5, 9, 10, 11, 15 and 16, 1891.



Another group of interesting minerals from a granitic district in Ulster is illustrated by the specimens here exhibited from the Mourne Mountains in County Down. This granite is especially interesting to collectors of minerals inasmuch as it presents in marked degree a *miarolitic* structure, that is—it contains numerous cavities which are lined with crystals of the constituent minerals. It is from these druses that the specimens here exhibited have been obtained. According to Prof. Sollas the granite of the Mourne Mountains is in all probability of Tertiary age\*—a view supported by other geologists.

In No. 1612 a drusy cavity contains rather large crystals of *orthoclase* associated with sharply defined crystals of *smoky quartz*, and with a dark *mica*. The granite of the Mourne Mountains contains also *albite*, or soda-felspar, as first pointed out by Dr. Haughton. In some of this granite the quartz, contrary to its usual habit, has consolidated before the felspar.

Among the accessory minerals of the granite, topaz and beryl occasionally occur as crystals studding the walls of the cavities. A beautiful crystal of colourless *Topaz*, of characteristic prismatic habit, is seen in No. 1616; whilst excellent crystals of *Beryl* will be found in the trays, Nos. 1613, 1614 and 1615. One of the beryls presents the form of a rather clear green prism, without the terminal plane; in another specimen the sea-green crystal shows the hexagonal prism combined with the basal pinacoid; whilst in a third specimen the prismatic crystal is opaque and fractured. The Irish beryls are further represented by three isolated crystals of blue colour, sufficiently clear to be cut as ornamental stones. These are in the tray, No. 1615. One of these is a magnificent crystal, presenting the form of a striated six-sided prism measuring two inches in length, translucent and bright blue at one end, but becoming white, dull and opaque towards the base. The basal plane is rough and is coated with a little oxide of iron. Transparent beryl, when of a bluish-green colour is known as *Aquamarine*.

A special group of minerals is yielded by the Tertiary volcanic rocks of the north-east of Ireland. These rocks are mostly basalts and dolerites, in many cases amygdaloidal, and containing zeolitic minerals of much beauty, closely resembling those of the Western Isles of Scotland. Prominent among the zeolites here exhibited are the specimens of *Analcite* or *analcime* (Nos. 1617 to 1619), mostly in dead white icositetrahedral crystals. In the specimen, No. 1619, however, the little sharply defined crystals are translucent or transparent, and are seated on "wacke," or decomposed trap-rock, from Benyevenagh. "It is an interesting fact," wrote Colonel Portlock in reference to the Irish analcime, "that the transparent varieties are invariably of a lower degree of hardness than the more opaque."†

---

\* "Preliminary Observations on the Granites of Wicklow and Down." *Scien. Proc. Roy. Dub. Soc.*, new series, vol. vi. (1888), p. 257.

† "Report on the Geology of the County of Londonderry, and of parts of Tyrone and Fermanagh." Dublin, 1843, p. 220.

One of the commonest of the Ulster zeolites is *Natrolite* (Nos. 1621, 1622)—a mineral which usually occurs in delicate white needle-like crystals, shooting across the cavities of the vesicular lava. Among the other so-called “basaltic minerals” mention may be made of *Antrimolite* (No. 1625) one of Dr. Thomson’s numerous “species” now regarded as a variety of *mesolite*. The specimen shows the antrimolite from the Giant’s Causeway in white botryoidal masses, of radio-fibrous structure. The *Levyne* (No. 1620), named by Sir D. Brewster after Lévy who made the catalogue of the Turner collection, seems to be a variety of *chabazite*, though much discussion has arisen with regard to its true relationship. *Gyrolite*, of which No. 1623 is a specimen, is a zeolite regarded by some as an altered form of apophyllite.

The dark green mineral in the basalt, No. 1626, is Thomson’s *Kirvanite*—a mineral which has perhaps resulted from the decomposition of the augitic constituent of the rock, and seems to be related to the group of rather ill-defined substances known as “green earth.”

No. 1627 is a specimen of basalt from the Isle of Muck, near Magee Island, off the east coast of Antrim, showing well-defined octahedral crystals of *magnetite* coated with brown oxide of iron. Even larger octahedra are seen on the fine specimen from Magee Island, No. 1628.

At the present day the iron-ores of Antrim are the most important minerals raised in Ireland. \* In the year 1902 the county yielded as much as 81,612 tons of ore. The “iron-ore measures” are an irregular series of iron oxides with clays and lignites, associated with volcanic tuffs, intercalated between the upper and lower groups of basalts and dolerites. Thin beds of bole, or ferruginous clay, resulting from the atmospheric disintegration of the volcanic rocks, occur between the successive lava flows at various horizons, especially in the Lower Basalts, but the great group of iron-bearing minerals, with the associated lignites and clays, forms a definite zone, probably of lacustrine origin, representing deposits in sheets of shallow water on the exposed surface of the older set of lava-flows. The richest ore is known from its structure, as *pisolitic iron-ore*, or *pebble ore* (No. 1629).† This is composed of small concretions of limonite or hæmatite, embedded in a matrix of ochreous clay. Somewhat similar concretionary ores are in course of formation at the present day at the bottom of certain lakes, especially in Sweden,

---

\* See *Mem. Geol. Surv. Explanatory Memoir*, Sheets 21, 28 and 29 (Ireland). By Edward Hull, M.A., F.R.S. (1876.) Also, Sheet 20. By R. Glascott Symes, M.A. (1886), and Sheet 19. By R. G. Symes and Alexander McHenry (1886).

† See “Notes on some of the Irish Crystalline Iron-Ores.” By G. H. Kinahan. *Sc. Proc. Roy. Dubl. Soc.*, new series, vol. iv. (1885), p. 306; also “Notes on the Tertiary Iron-Ore Measures, Glenariff Valley, County Antrim.” By Philip Argall. *Journ. Roy. Geol. Soc., Ireland*, new series, vol. vi. (1886), p. 98; and in *Sc. Proc. Roy. Dublin Soc.*, new series, vol. iii. (1883), p. 151.



where the deposition of the iron-oxide seems to be determined by the play of organic activities, whilst the ultimate source of the iron is probably referable to the decomposition of pyrites or of various iron-silicates in the crystalline rocks.

In the substance known as *Belfast aluminous ore* (No. 1630) the oxide of iron is associated with much alumina uncombined with silica, and the substance has thus acquired value as a fluxing agent in the reduction of siliceous ores, like certain kinds of hæmatite. It is sometimes regarded as a kind of bole. Aluminium hydroxide, in which iron replaces aluminium to a greater or less extent, is often termed *Bauxite*, from Les Beaux, a locality near Tarascon in the south of France; but the name has been used rather loosely and extended to various mineral substances, some of which pass into ferruginous clays. Bauxite is used in the preparation of aluminium and its salts. In the year 1902 the Irish bauxite (No. 1631) was raised to the extent of 9,047 tons. Alumina is prepared from this material at the works near Larne, and is sent thence to Foyers, in Inverness-shire, where it is reduced to the metallic state in the electric furnace.\* Some of the so-called bauxite of Antrim has been known as *alum clay*, but the proportion of silica is sometimes extremely low. Titanic oxide exists, however, to the extent of about 2 per cent. No. 1632 is a sample of the ferriferous clay known as *lithomarge*, which occurs with the iron-ore measures, and here presents the appearance of a speckled purple rock. The "pavement" is the name given locally to a poor kind of ore, on which the richer ore rests. At the Evishnably Mine the pisolitic ore yielded 35 to 40 per cent. of iron; the pavement about 28 per cent. and the violet lithomarge about 17 per cent.†

On the evidence of the vegetable remains preserved in certain leaf-beds between the Upper and the Lower basalts, it is inferred that the volcanic outbursts in the Antrim plateau go back to Oligocene or even to late Eocene time. The iron-ore measures seem to represent the denudation of the volcanic rocks during a prolonged pause between the earlier and the later episodes of volcanic activity.

Superficial deposits of *bog iron-ore* are found in various parts of Ulster, and the substance has in some cases been worked for use in the purification of coal-gas. The ore is an impure limonite, formed partly by organic agency.

Strata of Triassic age occur in County Antrim, and here as elsewhere the Keuper marls contain rock salt and gypsum. No. 1633 is a specimen of clear colourless crystalline salt, or *Halite*, from Maiden Mount Mine, near Carrickfergus. It appears that salt was first discovered in Antrim, while sinking for coal in 1850. At the present time the salt-measures are rather extensively worked

---

\* "Mineral Statistics" for 1902, p. 172.

† *Mem. Geol. Surv.* Memoir to accompany Sheet 20, Ireland. By R. Glascott Symes, M.A. (1886), p. 12.

in the neighbourhood of Carrickfergus.\* In the year 1902 the county of Antrim yielded 32,529 tons of rock-salt, and 12,063 tons of salt from brine-springs.

## MINERALS OF MUNSTER.

(Nos. 1634 to 1644.)

It is probable that the earliest workings for metalliferous minerals in the province of Munster were those in the copper deposits of the Knockmahon district, on the coast of Waterford. In this locality the "old men's workings" have yielded rude implements of stone and wood, pointing to mining operations at a remote period. The ores occur in lodes running through Lower Silurian (Ordovician) strata, associated with igneous rocks. No. 1634 is a sample of *copper-pyrites* from Knockmahon. The lodes yielding the copper also frequently carried silver-lead ores.†

Ores of cobalt have occasionally been found in association with the copper-ores of Waterford, and the specimen, No. 1635, from Bonmahon Head, shows the *erythrite*, or cobalt-bloom, in company with an incrustation of malachite; the characteristic pinkish tint of the former strikingly contrasting with the green colour of the latter.

Another group of copper-ores is represented by Nos. 1641 and 1642, from the south-western part of County Cork. Although the minerals are rather widely distributed throughout this district, it is only in a few localities that they have been found in sufficient quantity to be profitably worked. The Bearhaven or Allihies Mines, which at one time were extremely productive, are situated in a secluded part of the promontory between Kenmare and Bantry Bays. The ores occur in quartz-lodes coursing through killas, near the junction of what is often regarded as the Upper and the Lower Old Red Sandstone.‡ No. 1636 is a sample of *copper-pyrites* from Bearhaven, whilst No. 1637 is a specimen of *erubescite*, or purple copper-ore, from Ballycummisk Mine, near Skull.

Lead-ores, associated to some extent with the ores of zinc and copper, occur in the Carboniferous Limestone of County Clare. The specimen of coarsely crystalline *galena*, curiously striped, No. 1038, is from a pocket in the limestone at Ballyhicky Mine. An interesting mineral found in the Carboniferous rocks of Kilbrickan or Monanoe, in County Clare, was described by Dr. Apjohn as far back as 1840,

---

\* "The Salt Industry of Carrickfergus." By A. Miscampbell. *Trans. Fed. Inst.*, vol. vii. (1894), p. 546.

† *Mem. Geol. Surv.* Explanation of Sheets 167, 168, 178, and 179. By G. V. Du Noyer, 1865.

‡ *Ibid.* Explanation of Sheets 197 and 198 (1860). Notes on the mines by Warrington Smyth, M.A., F.R.S., p. 30. Also Explanation of Sheets 200, etc., 1861.



under the name of *Kilbrickanite* (No. 1639). This is a sulph-antimonite of lead which has been recently shown by Mr. G. T. Prior's analysis to be identical with the species *geocronite*. This analysis revealed the presence of arsenic to the extent of 4.59 per cent.\*

From a quarry of Carboniferous Limestone at Rockforest in County Cork, was obtained some years ago, the beautiful mineral which Prof. Harkness named *Cotterite*, in compliment to Miss Cotter through whom it was procured. A specimen is here exhibited, as No. 1640. This mineral is a variety of quartz, remarkable for its peculiar silvery lustre, associated with a pearly sheen. The cotterite forms thin laminæ, coating pyramidal quartz, and enclosing delicate films of limonite between the laminæ. It occurred in a quartz vein, covered by a thin layer of fine reddish clay, and Harkness suggested that the clay had yielded silica which was deposited on the quartz in a laminated form, the delicate lamination being responsible for the peculiar lustre.†

The series of Irish minerals is brought to a conclusion by several fine specimens of *Wavellite* (Nos. 1641 to 1644), from Clonmel in County Tipperary. These are beautiful mammillary masses of fibrous structure, displaying on fracture a radiate formation recalling that of the well-known wavellite of Devonshire, but on a rather bolder scale. Wavellite occurs likewise in the Lower Carboniferous rocks of Co. Cork.

## MINERALS OF THE ISLE OF MAN.

(Nos. 1645 to 1652.)

A few specimens placed at the end of the collection serve to represent, though imperfectly, the minerals of the Isle of Man. The mineral resources of the Island have been fully described by Mr. G. W. Lamplugh in his comprehensive official memoir,‡ a memoir in which he has given an historical account of local mining,§ and has added a list of all the minerals, comprising upwards of seventy species, known to occur in the island, whether in lodes or as rock-constituents.||

By far the most important minerals, from an economic point of view, are the ores of lead and zinc. The sample of *galena*, No. 1645, represents the lead-ore of the famous Foxdale Mine. Here, the lode, or system of lodes, runs in a direction almost due east and west for a distance of between two and three miles, and has been worked down to a depth of nearly 2,000 feet. The vein passes from the Manx slates into granite, and it is notable that although it is equally

\* "The Identity of Kilbrickanite with Geocronite." *Min. Mag.*, vol. xiii. (1902), p. 186.

† "On Cotterite, a new variety of Quartz." By Prof Harkness. *Min. Mag.*, vol. ii. (1878), p. 82.

‡ *Mem. Geol. Surv.* "The Geology of the Isle of Man." (1903.)

§ *Op. cit.*, p. 480.

|| *Op. cit.* p. 572.

productive in both types of "country," the galena in the slate or killas, is found to be richer in silver than that in the granite. In the specimen, No. 1645, which came from the Townsend Mine at Foxdale, and was presented by Capt. W. Kitto, the galena is crystallised in cubo-octahedra. In the specimen of *Polytelite*, or argentiferous fahl-ore, No. 1646, the proportion of silver, according to Mr. David Forbes, amounted to 13.57 per cent.\* This mineral was found in the easterly workings at Foxdale, where the lode passes into a granite country.

Another interesting mineral from the Foxdale Mines is the *Plumosite*, or "feather-ore," of which No. 1647 is an excellent example. This rare mineral was described by Sir Warrington Smyth, at the time of its discovery, about 1880.† It occurred in association with fine-grained galena and with vuggy or cellular quartz. The plumosite somewhat resembles cotton-wool, of dark colour, and consists of a felted mass of bright grey metallic hairs. It is a sulph-antimonite of lead, which may be regarded as a capillary variety of jamesonite. According to Capt. Kitto, the plumosite occurred only in the neighbourhood of galena that was rich in silver.

In the year 1902 the Foxdale Mines yielded 4,192 tons of lead-ore, from which 62,000 ounces of silver were obtainable. A large specimen of galena, in aggregated cubo-octahedra, associated with blende and dolomite, from the Laxey Mines, will be found in the lower part of the pedestal case, on the opposite side of the Museum, near Section Q of the Horse-shoe Case. This huge specimen was presented from the Great Exhibition of 1851.

Rich silver-lead ore was formerly raised at the famous Laxey Mines, and at one time copper-ore was produced there, but the workings at present are directed to the extraction of the ores of zinc. Nos. 1648, 1649, are samples of the *blende* of Great Laxey. The ores occur in a lode of very variable width, coursing in a north-and-south direction through slaty flags, of the Manx slate series. The chief minerals are blende and galena, in a gangue consisting mainly of quartz and calcite. In the Wall-case No. 12, on the opposite side of the room, are some very fine specimens of blende, with crystallised quartz, from the Laxey Mines, presented by Capt. Rowe. In the year 1902, Great Laxey yielded 963 tons of blende; whilst about the same amount was obtained from Snaefell Mine, situated three miles N.W. of the village of Laxey.

Very curious globular masses of radiated blende were yielded at one time by the Townsend or Cornelly Mine—a mine established on an east-and-west lode parallel to that of Foxdale. One of these spheroidal masses, presented in 1878 by Capt. Kitto, is exhibited in Wall-case 28. The specimen is broken across in order to display the radiate structure of the blende, and to expose the central mass of quartz and copper-pyrites.

---

\* "Researches in British Mineralogy." *Phil. Mag.*, 4 ser., vol. xxxiv. (1867), p. 329.

† *Trans. R. Geol. Soc., Corn.*, vol. x. (1887), p. 82.



In the specimen, No. 1650, from Laxey, crystals of *copper-pyrites* are seated on the eroded surface of a large rhombic dodecahedron of zinc blende. A very handsome specimen, of similar character, will be found in Wall-case 12. In No. 1651, also from Laxey, the copper-pyrites is crystallised on well-defined rhombohedra of *dolomite*. The latter mineral is by no means uncommon in some of the Manx lodes, and remarkably fine crystals occasionally occur. Copper-ore is found in subordinate quantity in many of the mineral-veins, but the most notable occurrence was at the old Bradda Mines, where the copper-pyrites was associated, as at most of the other localities, with argentiferous galena. The lode, forming a conspicuous feature in the fine cliffs of dark slaty rocks at Bradda Head, was regarded by Sir Warington Smyth as "the noblest surface exhibition of a mineral vein to be seen in Europe."

In discussing the origin of the metalliferous deposits in the Isle of Man, Mr. Lamplugh is disposed to connect them with the volcanic activity of the Tertiary period, suggesting that the fissures through which the igneous material of the dykes was brought up may have served also as conduits for the vapours and solutions which deposited the mineral matter of the lodes.

*Hæmatite* has been worked in the neighbourhood of Manghold Head, in the north of the island, where the ore occurs in bold veins coursing through the slaty rocks of the cliffs. The source of the hæmatite may probably be referred, as Mr. Lamplugh suggests, to the New Red strata which are believed to have formerly overlapped the slates.

The specimen, No. 1652, presented by Sir W. W. Smyth, in 1861, is a representative of the *anthracite*, which was found, at that time, in the Laxey Mines. This specimen was obtained from a depth of 110 fathoms. Unfortunately, the exact mode of its occurrence has not been recorded, and it remains doubtful whether it occurred as a constituent of the lode, or was derived from the adjacent slate. If really a vein-mineral, as some authorities have held, its origin may have been similar to that of certain graphitic substances that appear to have no relation with altered vegetable matter. The occurrence of *graphite*, in very limited quantity, has been recorded from the Snaefell lode and from Beary Mountain, in the heart of the Isle of Man. For a brief notice of the probable mode of formation of graphite, reference may be made to p. 160.

---

## INDEX.

---

- Actinium, 80.  
 Actinolite, 101.  
 Adipocere, mineral, 121.  
 Aerated Barytes, 170.  
 Aetites, 194.  
 Agate, 218.  
 Alabaster, 182.  
 Albite, 100.  
 Alcohol (galena) 137.  
 Allophane, Devon, 103.  
 — Kent, 200.  
 Alluvial Tin-ore, 18.  
 Almandine, 100.  
 Alquifoux, 137.  
 Alstonite, 171.  
 Alston Moor, minerals of, 161.  
 Alum clay, 230.  
 Aluminite, 201.  
 Aluminous iron-ore, 230.  
 Amber, 203.  
 Amethyst, 92.  
 Analcite (analcime) 217, 221, 228.  
 Anatase, 100, 128, 191.  
 Andradite, 101.  
 Andrews site, 53.  
 Anglesite, Anglesea, 127.  
 — Derbyshire, 139.  
 — Leadhills, 207.  
 Anhydrite, 185.  
 Anthracite, 234.  
 Antimonite, 59.  
 Antimony glance, 59.  
 — ores, 59.  
 Antrim iron-ores, 229.  
 Antrimolite, 229.  
 Apatelite, 197.  
 Apatite, Cornwall, 23.  
 — Cumberland, 153.  
 Apochromatic lenses, 87.  
 Aquamarine, 228.  
 Aragonite, Cumberland, 149, 172.  
 — Devon, 98.  
 — Leadhills, 210.  
 Argentite, 56.  
 Arsenic, 32.  
 Arsenical mundic, 31.  
 — pyrites, 31.  
 Asbestos, 129.  
 Asbolan, 125, 190.  
 Asphalt, 178, 179.  
 Associates of Cassiterite, 19, 21.  
 Atacamite, 49.  
 Aurichalite, Cumberland, 158, 167.  
 — Leadhills, 209.  
 Autunite, 83.  
 Axinite, 30.  
 Azurite, 46, 105, 190.  
 Babel quartz, 91.  
 Bagshot sands, 29.  
 Balls, ironstone, 119.  
 Barite, 168.  
 Barium in natural waters, 187.  
 Barytes, Cornwall, 95.  
 — Cumberland, 151, 168.  
 — Derbyshire, 135.  
 — in London Clay, 188.  
 — in Lower Greensand, 188.  
 — in Trias, 186.  
 Barytocalcite, 171.  
 Barytocelestite (barytocelestine), 115.  
 Bauxite 230.  
 Bayldonite, 53.  
 Beef (calcite), 202.  
 Beekite, 97.  
 Bell-metal ore, 20.  
 Beryl, Donegal, 227.  
 — Leinster, 225.  
 — Mourne Mountains, 228.  
 — Scotland, 220.  
 Bindheimite, 59.  
 Bismite, 79.  
 Bismuth, native, 78.  
 — glance, 79.  
 — ochre, 79.  
 — ores, 78.  
 Bismuthinite, 79.  
 Bismuthite, 79.  
 Bitumen, Elastic, 134.  
 Black cawk, 160.  
 — copper-ore, 38, 44.  
 — Jack, 141.  
 — lead, 159.  
 — muck, 145.  
 — oxide of manganese, 77.  
 — pyrites, 119.  
 Blackband ironstone, 119.  
 Blast ore, 144.  
 Bleierde, 138.  
 Bleinierite, 59.  
 Blende, Cornwall, 58.  
 — Cumberland, 165.  
 — Derbyshire, 140.  
 — Isle of Man, 233.  
 — Wales, 124.  
 — hexagonal, 214.  
 — ruby, 124.  
 Blister copper-ore, 36.  
 Bloodstone, 144.  
 Blue iron-earth, 71.  
 — John, 135.  
 — lead-ore, 55.  
 — stone, 127.  
 — vitriol, 46.



- Bogiron-ore, 193, 230.  
 Bornite, 39.  
 Botallackite, 49.  
 Bournonite, 62.  
 Boxes (pseudomorphs), 69.  
 Brass ore 158.  
 Brasses, 119.  
 Brendon Hills, iron-ores, 105.  
 Brewsterite, 211.  
 Bristol diamonds, 113.  
 — minerals of, 112.  
 Brochantite, 158.  
 Bromlite, 171.  
 Bronze, 8.  
 Brookite, 128.  
 Brown iron-ores, 193.  
 — lead-ore, 155.  
 Brush ore, 116.  
 Bull beef (fluor), 135.  
 Buntkupfererz, 39.  
 Butterfly twins (calcite), 132, 149.  
 Buttons of galena, 163.  
 Buxton diamonds, 136.  
 Cairngorm, 220.  
 Calamine, Cumberland, 166.  
 — Derbyshire, 141.  
 — Mendips, 109.  
 — pseudomorphs, 141.  
 Calcite, Cornwall, 93.  
 — Cumberland, 149, 172.  
 — Derbyshire, 132.  
 — Devon, 98.  
 — North Wales, 124.  
 — Strontian, 210.  
 Calco-uranite, 82.  
 Caldbeck Fells, minerals of, 152.  
 Caledonite, 208.  
 Campylite, 156.  
 Cann (fluor), 86.  
 Caoutchouc, mineral, 134.  
 Capels, 11, 28.  
 Capped quartz, 91.  
 Carlsbad twins, 14, 99.  
 Cassiterite, Cornwall, 8, 15.  
 — Ross-shire, 220.  
 — Wicklow, 223.  
 Cawk, 136.  
 Celadonite, 218.  
 Celestite (celestine), 113, 186.  
 Cellular quartz, 177.  
 Cement copper, 44, 127, 224.  
 Cerargyrite, 58.  
 Cerussite, Cornwall, 55.  
 — Cumberland, 165.  
 — Derbyshire, 138.  
 — Devon, 56.  
 — Leadhills, 207.  
 Chabazite, 217, 221.  
 Chalcantinite, 46.  
 Chalcedony, 96, 200.  
 Chalcocite, 37.  
 Chalcolite, 83.  
 Chalcophyllite, 53.  
 Chalcopyrite, 35.  
 Chalcosiderite, 54.  
 Chalcotrichite, 42.  
 Chalybite, Cornwall, 69.  
 — Devon, 69.  
 — Durham, 167.  
 — Somersetshire, 105.  
 Chamoisite, 192.  
 Chenevixite, 53.  
 Chessylite, 46, 105.  
 Chiasolite, 159.  
 Childrenite, 71.  
 Chloanthite, 75.  
 Chlor-apatite, 23.  
 Chlorite, 101.  
 Chloropal, 104.  
 Chlorophaeite, 222.  
 Chlorophane, 88.  
 Chromite, 222.  
 Chrysocola, 46.  
 Churchite, 83.  
 Clay iron-stone, 119.  
 Cleveland ore, 191.  
 Cinoclase, 52.  
 Clod (iron-marl), 116.  
 Cluthalite, 217.  
 Cobalt bloom, 76, 231.  
 Cobalt ores, Cornwall 75.  
 — Ireland, 231.  
 Cock's-comb barytes, 168.  
 — pyrites, 142.  
 Cog-wheel ore, 63.  
 Coke (calamine), 125.  
 Comby lodes, 21.  
 Condurrite, 64.  
 Connaught, minerals of, 226.  
 Connellite, 48.  
 Copaline, 203.  
 Copiapite, 197.  
 Copper mica, 53.  
 Copper, native 44, 213.  
 Copper ore, black 44.  
 —, red 42.  
 — vitreous 37.  
 Copper-ores, Cheshire, 189.  
 — Cornwall, 33.  
 — Devon 33.  
 — Ecton 142.  
 — Ireland, 224, 231.  
 — Leadhills, 209.  
 — N. Wales, 126.  
 Copper precipitate, 127, 224.  
 — pyrites, 35.  
 — shale, 189.  
 — uranite, 82.  
 Cornish diamonds, 91.  
 Cornwall, minerals of 5.  
 Cornwallite, 52.  
 Cotterite, 232.  
 Country (miner's term), 7.  
 Covellite, 38.  
 Crease, 116.  
 Crested barytes, 168.  
 Crocalite, 217.

- Cromfordite, 139.  
 Cronstedtite, 73.  
 Cross courses, 7, 54.  
 Cross-course spar, 91.  
 Crustification, 21.  
 Cube ore, 72.  
 Cumberland minerals, 143, 152, 161.  
 Cupreous Calamine, 158.  
 Cuprite, 42.  
 Cupro-uranite, 82.  
 Cyanite, 227.  
 Cyanosite, 46.  
  
 Dean Forest, minerals of, 116.  
 Delessite, 218.  
 Derbyshire, minerals of, 131, 137.  
 Desmine, 217.  
 Devilline, 47.  
 Devon, minerals of, 5.  
 Devonshire sand, 67.  
 Diallage, 103.  
 Dialogite, 77, 126.  
 Diamonds, Bristol, 113.  
 — Buxton, 136.  
 — Cornish, 91.  
 — Merthyr, 121.  
 Dogs (pyrites), 117.  
 Dog-tooth spar, 132.  
 Dolomite, Cornwall, 94.  
 — Cumberland, 149, 173.  
 — Isle of Man, 234.  
 — S. Wales, 118.  
 Dolomitic conglomerate, 111.  
 Dripstone, 133.  
 Druses, 65.  
 Dufreynite, 71.  
  
 Eagle-stones, 194.  
 Ecton minerals, 142.  
 Edingtonite, 218.  
 Eisenkiessel, 92, 113.  
 Elastic bitumen, 134.  
 Elaterite, 134.  
 Electric Calamine 159.  
 Electrum, 130.  
 Elvan, 7.  
 Endellionite, 63.  
 Enysite, 48.  
 Epidote, 159.  
 Epimorphs, 61.  
 Erubescite, 39.  
 Erythrite (erythrine), 76, 231.  
 Exmoor iron-ores, 106.  
 Eyam twins, calcite, 132.  
 Eye agate, 219.  
  
 Fahl-ore (Fahlerz), 64.  
 False lead, 141.  
 Felspar, 99  
 Felspar, kaolinisation of, 10.  
 Ferberite, 153.  
 Fire-stone, 199.  
 Flats, 132, 162.  
 Flint, 200.  
  
 Float-ore, 162.  
 Flos ferri, 172.  
 Fluellite, 26.  
 Fluor (fluorite or fluor-spar), Corn-  
 wall, 26, 85.  
 — Cumberland, 174.  
 — Derbyshire, 134.  
 — Devon, 86.  
 — N. Wales, 124.  
 Fluor-apatite, 23.  
 Fluorescence, 175.  
 Fluoroid, 86.  
 Forest of Dean, minerals of, 116.  
 Fossils, old use of wood, 5.  
 Fossil "oak" (barytes), 136.  
 Francolite, 24.  
 Fumaroles, 31.  
  
 Galactite, 217.  
 Galena, Cornwall, 55.  
 — Cumberland, 162.  
 — Derbyshire, 137.  
 — Devon, 55.  
 — Isle of Man, 232.  
 — Leadhills, 206.  
 — Mendips, 108.  
 — Strontian, 210.  
 — Wales, 118, 122, 123.  
 Gallium, in Cleveland ore, 192.  
 Gangue, 84.  
 Garnets, Cornwall, 100.  
 — Cumberland, 159.  
 — Donegal, 227.  
 Gas, natural, 204.  
 Geodes, 65.  
 Gilbertite, 27.  
 Glauconite, 195.  
 Goethite, 68.  
 Gold, Cornwall, 18.  
 — Ireland, 222.  
 — Scotland, 205.  
 — Wales, 129.  
 Goslarite, 139.  
 Gozzan (gossan), 41.  
 Graphite, Cornwall, 104,  
 — Cumberland, 159.  
 — Isle of Man, 234.  
 Gravel ore, 123.  
 Green lead-ore, 155.  
 — linnets, 139.  
 Greisen, 11.  
 Grey antimony-ore, 59.  
 — copper-ore, 38, 64.  
 — iron-ore, 116.  
 — manganese-ore, 77.  
 Groovers, 108.  
 Grossularia, 81.  
 Gruenlingite, 154.  
 Gypsum, in Purbeck beds, 185.  
 — in Trias, 182.  
 Gyrolite, 222, 229.  
  
 Hacked quartz, 91.  
 Haematite, Cornwall, 67.



- Haematite, Cumberland, 144.  
 — N. Wales, 125.  
 — S. Wales, 117.  
 Hair-pyrites, 120.  
 Halite, Cheshire, 181.  
 — Ireland, 230.  
 Halloysite, 103.  
 Hard-spar (quartz), 90.  
 Harmotome, 211.  
 Hatchettine, 121.  
 Haytorite, 97.  
 Health-stones, 198.  
 Heart-shaped calcite, 132, 149.  
 Heavy spar, 168.  
 Helium, 80.  
 Hemimorphite, Cumberland, 158.  
 — Leadhills, 209.  
 Henwoodite, 54.  
 Hepatic alteration of pyrites, 197.  
 Heulandite, 217.  
 Hexagonal blende, 214.  
 Highgate resin, 203.  
 Highlands of Scotland, minerals of, 219.  
 Hitchcockite, 156.  
 Horn silver, 58.  
 Hornstone, 97.  
 Horse-flesh ore, 39.  
 Huebnerite, 153.  
 Huel, 13.  
 Hydrargyllite, 99.  
 Hydro-haematite, 147.  
 Hydro-micas, 101.  
 Idocrase, 227.  
 Indigo copper, 39.  
 Ireland, minerals of, 222.  
 Iron bloom, 173.  
 Iron glance, 147.  
 Iron ores, Brendon Hills, 105.  
 ——— Bristol, 112.  
 ——— Cornwall, 65.  
 ——— Cumberland, 143.  
 ——— Devon, 65.  
 ——— Forest of Dean, 116.  
 ——— Jurassic, 191.  
 ——— Mendips, 110.  
 ——— Northamptonshire, 192.  
 ——— Yorkshire, 191.  
 ——— Weald, 193.  
 Iron Pyrites, Cornwall, 60.  
 ——— Cumberland, 167.  
 ——— Derbyshire, 142.  
 ——— Wicklow, 224.  
 ——— in Neozoic Strata, 196.  
 Iron-quartz, 92, 113.  
 Ironstone, clay, 119.  
 Iserine, 67.  
 Isle of Man, minerals of, 232.  
 Jamesonite, 59.  
 Jasper, 129, 219.  
 Jet, 202.  
 Jews'-house tin, 7, 17.  
 Joseite, 155.  
 Jurassic iron-ores, 191, 192.  
 Kilbrickanite, 232.  
 Killas, 7.  
 Killinite, 225.  
 Kilmacooite, 225.  
 Kirwanite, 229.  
 Kish, 160.  
 Kupfernickel, 75.  
 Kupferschiefer, 189.  
 Lake iron-ores, 229.  
 Lanarkite, 207.  
 Lancashire, haematite of, 143.  
 Langite, 47.  
 Lapis Calaminaris, 109.  
 Lateral secretion theory, 14.  
 Laumontite, 217, 221.  
 Lead-earth, 138.  
 Lead-glance, 137.  
 Lead-ores, Cornwall, 54.  
 ——— Cumberland, 161.  
 ——— Derbyshire, 137.  
 ——— Devon, 54.  
 ——— Isle of Man, 232.  
 ——— Leadhills, 206.  
 ——— Mendips, 107.  
 ——— Shropshire, 177.  
 ——— Strontian, 210.  
 ——— Triassic, 120.  
 ——— Wales, Mid., 122.  
 ——— Wales, N., 123.  
 ——— Wales, S., 118.  
 Leader, 10.  
 Leadhillite, Mendips, 108.  
 ——— Scotland, 208.  
 Leadhills, minerals of, 205.  
 Leicestershire, minerals of, 178.  
 Leinster, minerals of, 222.  
 Lepastrum, 188.  
 Lepidocrocite, 148.  
 Lepidolite, 27.  
 Levyne, 229.  
 Liassic iron-ores, 191.  
 Libethenite, 51.  
 Lime-uranite, 82.  
 Limnite, 195.  
 Limonite, 68, 117, 194.  
 Linarite, Cumberland 157.  
 ——— Leadhills, 208.  
 Linnets, 139.  
 Liroconite, 52.  
 Lithia mica, 27.  
 Lithomarge, 103, 230.  
 Lodes, 6.  
 Loughs, 147.  
 Ludlamite, 71.  
 Lunnite, 52.  
 Luxullianite, 29.  
 Lyellite, 47.  
 Magnesite, 102.

- Magnetic pyrites, 168.  
 Magnetite, Cornwall, 66  
   — Devon, 66.  
   — Ireland, 229.  
   — Yorkshire, 192.  
 Malachite 46, 105, 157.  
 Malleable copper, 44.  
 Man, Isle of, minerals of, 232.  
 Manganese nodules, 126.  
 Manganese-ores, Cornwall, 76.  
   — Devon, 76.  
   — N. Wales, 125.  
 Manganese-Spar, 77.  
 Manganite, 77.  
 Marcasite, 198.  
 Marmatite, 58.  
 Martite, 66.  
 Matlockite, 139.  
 Melaconite, 43.  
 Melanterite, 197.  
 Menaccanite, 67.  
 Mendip Hills, minerals of, 107.  
 Mendipite, 108.  
 Merthyr diamonds, 121.  
 Mesolite, 217, 222, 229.  
 Metalliferous slates, Wales, 121.  
 Mexico, Huel, 57.  
 Miarolitic structure, 228.  
 Mica, 27.  
 Micaceous iron-ore, 67.  
 Midland Valley, Scotland, minerals of, 213.  
 Mid-Wales, minerals of, 121.  
 Milky quartz, 129.  
 Millerite, 120.  
 Mimetite, Cornwall, 56.  
   — Cumberland, 156.  
 Mineral adipocere, 121.  
   — caoutchouc, 134.  
 Minette, 192.  
 Miniun, native, 206.  
 Mispickel, 31, 62.  
 Mock-ore, 141.  
 Molybdenite, 154, 179.  
 Molybdic ochre, 154.  
 Molybdite, 154.  
 Monazite, 100.  
 Moonstone, 183.  
 Morvenite, 212.  
 Moss agate, 219.  
 Mother of lead, 163.  
 Mottramite, 191.  
 Mourne Mountains, minerals of, 228.  
 Mundic, 60.  
   — Arsenical, 31.  
 Munster, minerals of, 231.  
 Murchisonite, 100.  
 Nail-headed calcite, 172.  
   — copper-ore, 37.  
 Native bismuth, 78.  
   — copper, 44, 213.  
   — gold, 18, 129, 205, 222.  
 Native silver, 57.  
   — sulphur, 226.  
 Natrolite, 217, 229.  
 Natural gas, 204.  
 Needle iron-ore, 68.  
   — tinstone, 16.  
 Neozoic strata, 180.  
 Niccolite, 75.  
 Nickel, 120.  
   — ores, Cornish, 75.  
   — pyrites, 120.  
 Nigrine, 227.  
 North Wales, minerals of, 123.  
 Northampton iron-ore, 192.  
 Ochre, 111.  
 Olivenite, 51.  
 Onyx, 219.  
 Onyx barytes, 136.  
   — marble, 173.  
 Oolitic iron-ores, 191.  
 Opal, 97.  
 Orthoclase, 99.  
 Paragenesis, 19.  
 Passyite, 199.  
 Peach, 101.  
 Peacock copper-ore, 36.  
 Pearl spar, Cornwall, 94.  
   —, Cumberland, 149.  
 Pebble iron-ore, 229.  
 Pebbles, Scotch, 218.  
 Pectolite, 218, 222.  
 Pencil-ore, 144.  
 Pentlandite, 75.  
 Penwithite, 78.  
 Pharmacosiderite, 72.  
 Phillipsite, 39.  
 Phosgenite, 139.  
 Pigotite, 104.  
 Pinite, 100.  
 Pins, ironstone, 119.  
 Pipe veins, 132.  
 Pisolitic iron-ore, Antrim, 229.  
   — North Wales, 126.  
 Pitchblende, 79.  
 Plaster stone, 183.  
 Plumbago, 159.  
 Plumbo-aragonite, 209.  
 Plumbo-calcite, 209.  
 Plumosite, 233.  
 Plush, copper-ore, 42.  
 Pneumatolysis, 11.  
 Poder, 44.  
 Polianite, 77.  
 Polonium, 80.  
 Polytelite, 233.  
 Potato-stones, 111.  
 Potters' ore, 137.  
   — stone, 183.  
 Precipitate, copper, Anglesea, 127.  
   — Wicklow, 224.  
 Prehnite, 101, 216.  
 Przibramite, 214.



- Pseudomalachite, 52.  
 Pseudomorphs, 13, 55, 69, 142, 146, 163.  
 Pseudophite, 102.  
 Psilomelane, 77.  
 Puddle-ore, 145.  
 Purple copper-ore, 39.  
 Pyrargyrite, 57.  
 Pyrites (pyrite), Cornwall, 60.  
 — Forest-of-Dean, 117.  
 — S. Wales, 119.  
 — in Neozoic strata, 196.  
 Pyrites, arsenical, 31.  
 — hair, 120.  
 — magnetic, 168.  
 — nickel, 120.  
 — rhombic, 198.  
 — tin, 20.  
 Pyritohedron, 61.  
 Pyritoids, 62.  
 Pyroelectricity, 159.  
 Pyroemerald, 88.  
 Pyrolusite, 77.  
 Pyromorphite, Cornwall, 56.  
 — Cumberland, 155.  
 — Leadhills, 207.  
 Pyrophosphorescence, 88.  
 Pyrrhotite (pyrrhotine), 167.  
  
 Quartz, Cornwall, 21, 90.  
 — Cumberland, 148, 176.  
 — Snowdon, 129.  
 — in Neozoic strata, 199.  
 Quartz, milky, 129.  
  
 Radio-active minerals, 80.  
 Radio-tellurium, 80.  
 Radium, 80.  
 Rake veins, 131, 161.  
 Rashleigh collection, 62.  
 Ratholite, 218.  
 Red copper-ore, 42.  
 — iron-ore, 144.  
 Reddle, 111.  
 Redruthite, 37.  
 Re-entrant angles, 15.  
 Resin, Highgate, 203.  
 Restormel Royal Mine, 65.  
 Restormelite, 103.  
 Retinasphalt, 104.  
 Retinite, 104.  
 Rhodochrosite, 77.  
 Rhodonite, 78, 126.  
 Ribband veinstones, 21.  
 Right-running veins, 161.  
 Rock-crystal, 91.  
 Rock-salt, 181, 230.  
 Roscoelite, 191.  
 Rose spar, 77.  
 Rosedale iron-ore, 192.  
 Rosin blende, 141.  
 — tin, 16.  
 Round ore (galena), 123.  
 Ruby blende, 124.  
 Ruby copper-ore, 42.  
 Ruddle, 111, 144.  
 Rugg stones, 199.  
 Rutile, 100, 128, 226.  
  
 Saline alteration of pyrites, 197.  
 Salt, Cheshire, 181.  
 — Ireland, 230.  
 Sammetblende, 68.  
 Sanidine, 99.  
 Saponite, 103.  
 Satin-spar, 173, 183.  
 Saussurite, 103.  
 Scarbroite, 200.  
 Sceptre quartz, 225.  
 Schaumkalk, 173.  
 Scheelite 31, 153.  
 Schiefer spar, 93, 210.  
 Schillerisation, 103.  
 Schorl, 28.  
 Schorl-rock, 29.  
 Schroetterite, 103.  
 Scorodite, 73.  
 Scotch pebbles, 218.  
 Scotland, minerals of, 205.  
 Seals on crystals, 162.  
 Secretion, lateral 14.  
 Selenite, 183.  
 Serpentine, 102.  
 Shining ore, 67.  
 Shropshire, minerals of 177.  
 Siderite, 69.  
 Sidot's blende, 214.  
 Silver, native, 57.  
 Silver ores, Cornwall, 56.  
 Slate spar, 93, 210.  
 Slickensides, 138.  
 Slippers (pseudomorphs), 70.  
 Smaltite (smaltine) 76.  
 Smith ore, 116.  
 Smithsonite 158.  
 Smoky quartz, 91, 148, 220.  
 Smoky topaz, 220.  
 Soap stone, 103.  
 Solfatara, 31.  
 Somersetshire, minerals of, 105.  
 Soot, arsenical, 32.  
 Spangolite, 48.  
 Sparable tin, 16.  
 Sparry iron-ore, 106.  
 Spathic iron-ore, 106.  
 Spatum Islandicum, 124.  
 Specular iron-ore, 67, 147.  
 Sphaerosiderite, 120.  
 Sphalerite, 58, 141.  
 Stalactites, 133, 202.  
 Stalactitic barytes, 136.  
 Stalagmites, 133, 202.  
 Stannite (stannine), 20, 23.  
 Steatite, 103.  
 Stephanite, 57.  
 Stibnite, 59.  
 Stilbite, 217, 221.  
 Stilpnosiderite, 195.

Stokesite, 23.  
 Stream tin, 17.  
 Strontian, minerals of, 210.  
 Strontian spar, 211.  
 Strontianite, 211.  
 Strontium, 114, 211.  
 Sugar-candy spar, 98, 202.  
 Sugary spar, 21.  
 Sulphur, native, 185, 226.  
 Sulphur-ore, 224.  
 Susannite, 208.

Tallingite, 49.  
 Tamarite, 53.  
 Tarnowitzite, 209.  
 Tavistockite, 99.  
 Tennantite, 64.  
 Tenorite, 44.  
 Terra ponderosa, 170.  
 Tetradymite, 154.  
 Tetrahedrite, 64.  
 Thomsonite, 216.  
 Thunderbolts, 198.  
 Tile-ore, 42.  
 Tin, black, 8.  
 —, native, 7.  
 —, needle, 16.  
 —, sparable, 16.  
 —, white, 8.  
 Tin-ore, 15, 220, 223.  
 Tin pyrites, 20.  
 Tinstone, Cornwall 15.  
 — Ross-shire, 220.  
 — Wicklow, 223.  
 Titanium, 191.  
 Toad's-eye tin, 17.  
 Toadstone, 131.  
 Tooth-tin, 16.  
 Topaz, Cornwall 25.  
 — Ireland, 228.  
 — Scotland, 220.  
 Torberite (Torbernite), 83.  
 Tourmaline, 28.  
 Towanite, 35.  
 Travertine, 133.  
 Troilite, 141.  
 Trowlesworthite, 26.  
 Tungstic ochre, 153.  
 Tungstite, 31, 153.  
 Turf copper-mine, 127.  
 Turgite, 147.

Ulster, minerals of, 227.  
 Unstable quartz, 92.  
 Uraninite, 79.  
 Uranite, 81.  
 Uranium mica, 82.  
 — ochre, 81.  
 — ores, 79.

Vadose region, 41.  
 Vanadinite, 207.  
 Variegated copper-ore, 39.  
 Variscite, 179.  
 Veins, mineral, 6, 84.  
 Vesuvian, 227.  
 Virgin copper, 44.  
 Vitreous copper ore, 37.  
 Vivianite, 70.  
 Volborthite, 191.  
 Vugs, 6, 85.

Wad, 159.  
 Wales, minerals of, 117.  
 Waringtonite, 47.  
 Wavellite, Devon, 98.  
 — Ireland, 232.  
 Waxed vein, 138.  
 Wealden iron-ore, 193.  
 Websterite, 201.  
 Welsh Gold, 129.  
 Western Isles, minerals of, 221.  
 Wheal, 13.  
 Wheat stone, 138.  
 White iron-ore, 106.  
 White lead-ore, 138.  
 Wicklow, copper, 224.  
 — gold, 222.  
 Willemite, 158.  
 Withamite, 219.  
 Witherite, 170, 178.  
 Wolfram, Cornwall, 30.  
 — Cumberland, 153.  
 Wolframine, 31.  
 Wolframite, 30.  
 Wolfram ochre, 31.  
 Wonder stone, 202.  
 Wood arsenate, 51.  
 — copper, 51.  
 — iron-ore, 68.  
 — tin, 16.  
 Woodwardite, 47.  
 Wulfenite, 154.

Xanthosiderite, 195.

Yellow copper-ore, 35.

Zeolites, 215, 221.  
 Zinc-ores, Cornwall, 58.  
 — Cumberland, 165.  
 — Derbyshire, 140.  
 — Isle of Man, 233.  
 — Leadhills, 209.  
 — Mendips, 109.  
 Ziunwaldite, 27.  
 Zippeite, 81.  
 Zwitter, 12.







- NW - DISS, EYE, &c. By F. J. BENNETT. 2s.  
 NE - HALESWORTH and HARLESTON. By W. WHITAKER and W. H. DALTON. 1s.  
 SE - BURY ST. EDMUNDS and NEWMARKET. By F. J. BENNETT, J. H. BLAKE, and W. WHITAKER. 1s.  
 NE - PARTS of CAMBRIDGESHIRE and SUFFOLK. By W. WHITAKER [and Others]. 2s.  
 SE - PART of NORTHAMPTONSHIRE. By W. T. AVELINE and RICHARD TRENCH. 8d.  
 NE - PARTS of NORTHAMPTONSHIRE and WARWICKSHIRE. By W. T. AVELINE. 8d.  
 - S.W. NORFOLK and N. CAMBS. By W. WHITAKER, S. B. J. SKERTCHLY, and A. J. JUKES-BROWNE. 3s.  
 SW - ATTLEBOROUGH. By F. J. BENNETT. 1s. 6d.  
 NW - E. DEREHAM. By J. H. BLAKE. 1s. 6d.  
 - YARMOUTH and LOWESTOFT. By J. H. BLAKE. 2s.  
 E - CROMER. By C. REID. 6s.  
 NW, SW - FAKENHAM, WELLS, &c. By H. B. WOODWARD. 2s.  
 - BORDERS of THE WASH. By W. WHITAKER, and A. J. JUKES-BROWNE. 3s.  
 - S. W. LINCOLNSHIRE, &c. By A. J. JUKES-BROWNE, and W. H. DALTON. 4s.  
 NE - NOTTINGHAM. By W. T. AVELINE. (2nd Ed.) 1s.  
 NW - RHYL, ABERGELE, and COLWYN. By A. STRAHAN. (Notes by R. H. TIDDEMAN). 1s. 6d.  
 SE - FLINT, MOLD, and RUTHIN. By A. STRAHAN. (Parts by C. E. DE RANCE). 4s. 6d.; *Supplement* 2d.  
 NW - PRESCOT, LANCASHIRE. By E. HULL. (3rd Ed. With additions by A. STRAHAN.) 3s.  
 SW - CHESTER. By A. STRAHAN. 2s.  
 NW, SW - STOCKPORT, MACCLESFIELD, CONGLETON, and LEEK. By E. HULL and A. H. GREEN. 4s.  
 SE - PARTS of NOTTINGHAMSHIRE and DERBYSHIRE. By W. T. AVELINE. (2nd Ed.) 6d.  
 NE - PARTS of NOTTINGHAMSHIRE, YORKSHIRE, and DERBYSHIRE. (2nd Ed.) By W. T. AVELINE. 1s.  
 - LINCOLN. By W. A. E. USSHER, A. J. JUKES-BROWNE, and A. STRAHAN. 3s.  
 - EAST LINCOLNSHIRE. By A. J. JUKES-BROWNE. 3s. 6d.  
 - N. LINCOLNSHIRE and S. YORKSHIRE. By W. A. E. USSHER [and Others]. 2s.  
 NW - WAKEFIELD and PONTEFRAC. By A. H. GREEN. 6d.  
 SW - BARNLEY. By A. H. GREEN. 9d.  
 SW - OLDHAM. By E. HULL. 2s.  
 SE - PART of the YORKSHIRE COALFIELD. By A. H. GREEN, J. R. DAKYNS, and J. C. WARD. 1s.  
 NE - DEWSBURY, &c. By A. H. GREEN, J. R. DAKYNS, J. C. WARD, and R. RUSSELL. 6d.  
 SE - BOLTON, LANCASHIRE. By E. HULL. 2s.  
 SE - COUNTRY between LIVERPOOL and SOUTHPORT. By C. E. DE RANCE. 3d.  
 NE - SOUTHPORT, LYTHAM, and SOUTH SHORE. By C. E. DE RANCE. 6d.  
 SW - COUNTRY between BLACKPOOL and FLEETWOOD. By C. E. DE RANCE. 6d.  
 NW - SOUTHERN PART of the FURNESS DISTRICT in N. LANCASHIRE. By W. T. AVELINE. 6d.  
 SE - BRADFORD and SKIPTON. By J. R. DAKYNS, C. FOX-STRANGWAYS, R. RUSSELL, and W. H. DALTON. 6d.  
 NW - NORTH and EAST of HARROGATE. By C. FOX-STRANGWAYS. 6d.  
 NE - COUNTRY between YORK and MALTON. By C. FOX-STRANGWAYS. 1s. 6d.  
 NW - N. and E. of LEEDS and near TADCASTER. By W. T. AVELINE, A. H. GREEN (and Others). 6d.  
 SE, 94 SW - COUNTRY between YORK and HULL. By J. R. DAKYNS, C. FOX-STRANGWAYS, and A. G. CAMERON. 1s. 6d.  
 NW - DRIFFIELD. By J. R. DAKYNS and C. FOX-STRANGWAYS. 9d.  
 NE - BRIDLINGTON BAY. By J. R. DAKYNS and C. FOX-STRANGWAYS. 1s.  
 SW, SE - SCARBOROUGH and FLAMBOROUGH HEAD. By C. FOX-STRANGWAYS. (2nd Ed.) 1s.  
 NW - WHITEBY and SCARBOROUGH. By C. FOX-STRANGWAYS and G. BARROW. 1s. 6d.  
 SE - NEW MALTON, PICKERING, and HELMSLEY. By C. FOX-STRANGWAYS. 1s.  
 NE - ESKDALE, ROSEDALE, &c. By C. FOX-STRANGWAYS, C. REID, and G. BARROW. 1s. 6d.  
 NW, SW - NORTHALLERTON and THIRSK. By C. FOX-STRANGWAYS, A. G. CAMERON, and G. BARROW. 1s. 6d.  
 SW - INGLEBOROUGH. By J. R. DAKYNS, R. H. TIDDEMAN, W. GUNN, and A. STRAHAN. 2s.  
 NW - MALLERSTANG. By J. R. DAKYNS, R. H. TIDDEMAN [and Others]. 3s. 6d.  
 NE - KENDAL. By W. T. AVELINE and T. MC K. HUGHES. 2nd Ed. by A. STRAHAN. 2s.  
 SW - APPLEBY, &c. By J. R. DAKYNS, R. H. TIDDEMAN, and J. G. GOODCHILD. 1s. 6d.  
 SW, SE - NORTH CLEVELAND. By G. BARROW. 1s. 6d.  
 - CARLISLE. By T. V. HOLMES. 1s. 3d.  
 SE - OTTERBURN and ELSDON. By HUGH MILLER. 2s. 6d.  
 NE - CHEVIOT HILLS. By C. T. CLOUGH. 1s. 6d.  
 SW - PLASHETTS and KIELDER. By C. T. CLOUGH. 1s.  
 SW - WOOLER and COLDSTREAM. By W. GUNN and C. T. CLOUGH. 1s. 6d.  
 NW - NORHAM and TWEEDMOUTH. By W. GUNN. 6d.  
 NE - COAST SOUTH of BERWICK-ON-TWEED. By W. GUNN. 9d.  
 SE - BELFORD, HOLY ID, and FARNE ISLANDS. By W. GUNN. 2s. 6d.

#### SHEET MEMOIRS OF NEW SERIES MAPS.

- STOKE-UPON-TRENT. By W. GIBSON and C. B. WEDD. Price 1s. 6d.  
 - ATHERSTONE and CHARNWOOD FOREST. By C. FOX-STRANGWAYS. 2s.  
 - LEICESTER. By C. FOX-STRANGWAYS. 3s.  
 - ABERGAVENNY. By A. STRAHAN and W. GIBSON. 2s.  
 - PONTYPRIDD. By A. STRAHAN, R. H. TIDDEMAN, and W. GIBSON. 1s. 6d.  
 - NEWPORT, MON. By A. STRAHAN. 2s.  
 - CARDIFF. By A. STRAHAN and T. C. CANTRILL. 2s. 3d.  
 - READING. By J. H. BLAKE and H. W. MONCKTON. 1s. 6d.  
 - SALISBURY. By C. REID [and Others]. 1s. 3d.  
 - RINGWOOD. By C. REID [and Others]. 1s.  
 - SOUTHAMPTON. By C. REID. 1s. 6d.  
 - CHICHESTER. By C. REID, G. W. LAMPLUGH, and A. J. JUKES-BROWNE. 1s.  
 - EXETER. By W. A. E. USSHER. 2s.  
 - DORCHESTER. By C. REID. 1s.  
 - BOURNEMOUTH. By C. REID. 4d.  
 - BOGNOR. By C. REID. 6d.  
 - EASTBOURNE. By C. REID. 6d.  
 - TORQUAY. By W. A. E. USSHER. 2s.



**THE MUSEUM OF PRACTICAL GEOLOGY,**

**Jermyn Street, S.W.,**

Is open to the Public FREE on every week-day, except Christmas Day and Good Friday, and on ~~Saturdays~~ from 2 o'clock to 4, 5 or 6 o'clock, according to the time of the year.

On Mondays and Saturdays the Museum is open from 10 o'clock a.m. until 10 o'clock p.m. On other days the Museum is open from 10 a.m. until 4 o'clock p.m. during the months of November, December, January, and February, and until 5 o'clock during the rest of the year.











**TO** 

642-2997

## 1 MONTH

2

3

4

5

6

Books needed for class reserve are subject to immediate recall

**DUE AS STAMPED BELOW**

[illegible]

UNIVERSITY OF CALIFORNIA, BERKELEY  
BERKELEY, CA 94720

Storage



C034635057

-313





